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VOL. 17 JANUARY, 1927 No. 1

THE HYDRAULIC JUMP AS A MIXING DEVICE[1,2]

BY A. G. LEVY[3] AND J. W. ELLMS[4]

The hydraulic jump may be defined as that phenomenon in which a part of the kinetic energy of a stream of water flowing in an open channel, at less than the critical depth, is converted into potential energy in the attempted turbulent passage from the lower to the upper alternative flow level. These alternative levels are the only two possible levels for steady flow under a given energy condition; and the critical depth is that depth at which the alternative levels coincide. For any given channel section and given quantity of water, the critical depth is a constant, and represents the minimum amount of energy for that particular set of conditions. In other words, the critical depth for any given discharge per unit width is that depth for which the value of the sum of the depth and the velocity head is a minimum.

In considering the alternative flow levels in an open channel, it must be borne in mind that the passage from the low to the high

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[1] Presented before the Water Purification Division, Buffalo Convention, June 11, 1926.

[2] U. S. Patent 1,362,611, December 21, 1920.

[3] Engineer of Construction and Surveys, Division of Water, Cleveland, Ohio.

[4] Engineer of Water Purification and Sewage Disposal, Division of Water, Cleveland, Ohio.

stage is possible under two conditions; namely, (1) without the presence of any turbulence, and (2) by means of the jump, involving loss of energy through internal impact. The first case can never happen except by the interposition of a force external to the water itself and the second can take place only through the loss of energy within the jump.

These conditions necessarily follow from the theories of the conservation of linear momentum and energy. Because of the loss within the jump, the upper alternative theoretical flow level can never be actually reached, although it is the attempt of the water to pass to it which results in the jump taking place.

The hydraulic jump, as a phenomenon of nature, occurs along lake and sea shores under certain conditions of beach formations. It is found at the foot of high dams and occasionally in channels for irrigation works. It is often a source of trouble and requires special care to avoid its occurrence whenever any condition exists which causes retardation of velocity in a stream flowing much below its critical depth.

The hydraulic jump has been studied experimentally for over one hundred years. According to the technical report of the Miami Conservancy District, Bidone's results, published on pages 21 to 80, in the Transactions of the Royal Societies of Turin for the year 1819, are the earliest on record. Professor Gibson, Ferriday and others, and lately Lane, Kennison, Hinds, and Riegel and Beebe, have made similar studies. With the exception of the work conducted by Riegel and Beebe for the Miami Conservancy District all experiments have been made upon small flows of water. The work carried on in the Cleveland experiments involved quantities, varying from a minimum of approximately 20 to a maximum of 42 cubic feet per second. These volumes are roughly from 2 to 4 times as large as any heretofore handled experimentally.

The hydraulic jump, while a common phenomenon in nature, has, so far as the writers know, been utilized only occasionally, and then solely for the dissipation of energy in flowing water. Engineers have employed the hydraulic jump with the idea of changing a high velocity of flow, which would cause scour, into the more stable and less destructive low velocity. In no case, however, so far as we are aware, has an attempt been previously made to convert the energy within the jump itself into useful work.

It was thought that the churning action therein would furnish a cheap and efficient means for thoroughly mixing water, being prepared for filtration, with the chemicals applied. In order to test this hypothesis, it was necessary (1) to study the action of the jump from the standpoint of a method for chemical mixing, and (2) to investigate, on a sufficiently large scale, its practicability for the conditions required in good filtration plant design. Both of these objectives were attained as a result of the Cleveland experiments.

In principle, the hydraulic jump and mixing flume, together with the phenomena of which the jump is a part, are shown on figure 1. As may be noted, the mixing device consists of an approach with a rounded entrance to the narrow section or throat, the latter leading to an expanding flume set on a slope. This flume is followed by a lower pool from which, in general, some type of control section leads to the exit channel. As the water enters the throat, it drops to its critical depth. From this point, it is theoretically possible for it to move along either the upper or the lower alternative flow levels, but because of the sloping, expanding flume, and because the surface of the tail water; viz., the water in the lower pool, is below the upper alternative flow level, the water is forced into the lower flow level until it meets the tail water where it attempts to jump to the higher level at the section marked "location of jump." As shown, the tail water depth is its distance above the floor of the lower pool at a point where the water is sensibly level and the loss of head is the difference in elevation between the surface of the water in the upper pool and that in the lower.

DESCRIPTION OF APPARATUS

The investigations of the hydraulic jump as a chemical mixing device were carried out by the Cleveland Water Department under the direction of the writers. The experimental plant was located at the Kirtland Pumping Station, situated on the Lake front at East 49th Street. The apparatus, as originally built, consisted of a stilling chamber, approximately 20 feet long by 10 feet wide by 9 feet deep with a baffle 3.95 feet high, which extended across the chamber, approximately 17 feet distant from the end at which the water entered. Leading from the other end of the stilling chamber and approximately 3 feet above the bottom was an expanding flume, having a sharp entrance, 4.90 feet wide at the narrow end, and 10.22 feet wide at the opposite end. The expanding flume was 20.72 feet long and had a drop of 3.06 feet in its entire length. This flume led

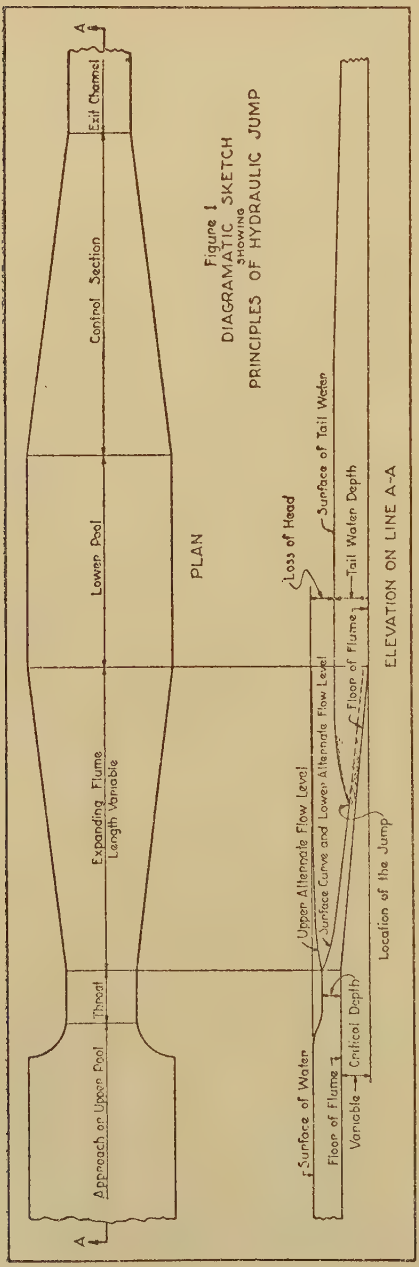
Figure 1
DIAGRAMATIC SKETCH
SHOWING
PRINCIPLES OF HYDRAULIC JUMP
A
A
Approach or Upper Pool
Throat
Expanding Flume
Length Variable
Lower Pool
Control Section
Exit Channel
PLAN
Surface of Water
Floor of Flume
Variable
Critical Depth
Upper Alternate Flow Level
Surface Curve and Lower Alternate Flow Level
Location of the Jump
Floor of Flume
Loss of Head
Surface of Tail Water
Tail Water Depth
Floor of Flume
ELEVATION ON LINE A-A

FIG. 1

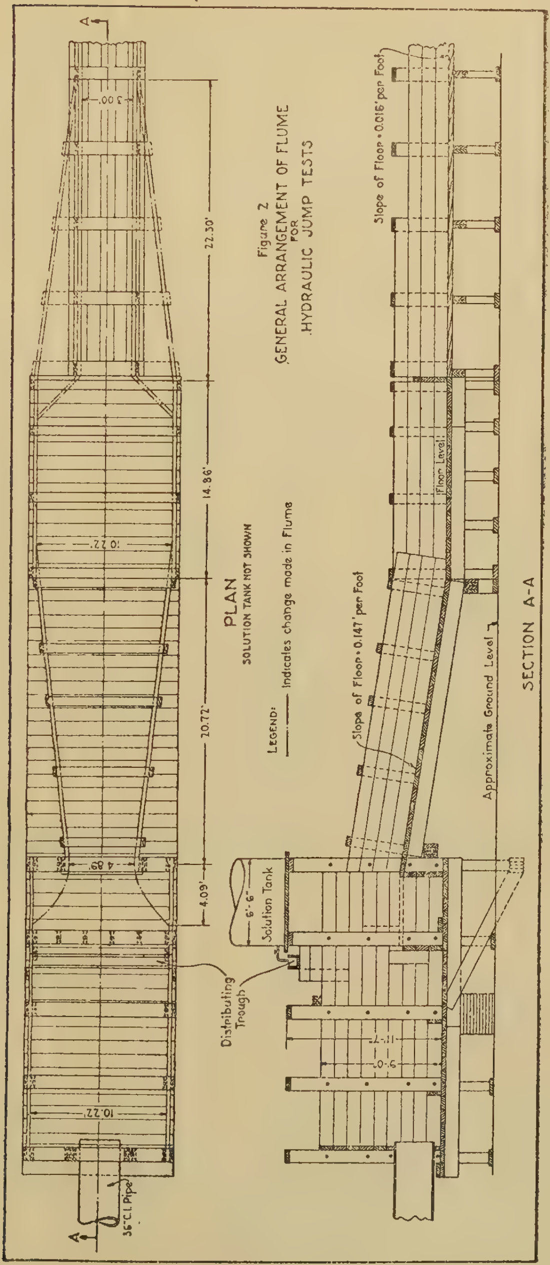
Figure 2
GENERAL ARRANGEMENT OF FLUME
FOR
HYDRAULIC JUMP TESTS
PLAN
SOLUTION TANK NOT SHOWN
LEGEND:
Indicates change made in Flume
SECTION A-A
A
A
3.00'
22.30'
14.86'
10.22'
20.72'
4.89'
4.09'
10.22'
36" C.I. Pipe
Distributing Trough
6'-6"
Solution Tank
11'-7"
9'-0"
Slope of Floor = 0.016' per Foot
Floor Level
Slope of Floor = 0.147' per Foot
Approximate Ground Level

FIG. 2

into a chamber approximately 14 feet by 10.22 feet wide. At the end of this chamber, opposite the point at which the expanding flume entered, was an exit flume approximately 3 feet wide with a slope of 0.016 feet, per foot. This flume led directly to the lake shore and was intended merely to convey the water after it had passed through the jump. As constructed, the layout is shown on figure 2.

Over the stilling chamber and supported by struts on line with the baffle, was a platform on which rested a circular chemical tank, 6.5 feet in diameter. This tank was fed by a 2-inch pipe line which furnished the water for preparing the solution. For mixing and dissolving the chemicals, an air and steam pipe grid was placed in the tank near the bottom. A drain line led from the bottom of the tank to the ground level, from which point sludge and etc., could be flushed into the sewer. Just alongside the platform on which the chemical tank stood, and spanning the width of the stilling chamber was a box with V notch weirs cut in the side. Chemical piping led from the tank to the weir box.

For measuring depths of water, glass gauges were placed at approximately 2-foot intervals along the wall of the expanding flume and at two or three other strategic points. The entrance to these gauges was near the floor of the flume and flush with the inside face. One-eighth-inch piping, made in the form of quarter bends, were driven through the flume wall with one leg of the bends standing vertically on the outside. The glass gauges were connected to these pipes with rubber tubing, and were held by clamps to gauge boards on which were scales graduated to 0.01 of a foot. To prevent surging a laboratory clamp was placed on each rubber connection.

The gauges, explained in the last paragraph, were ultimately found to be unsatisfactory, and there were substituted for them, that which we have termed the forked gauge. This gauge consisted of two parts; namely, (1) a one-sided movable bridge about 12 feet long, spanning the flume walls, and (2) a fork for measuring to the water surface and flume floor. The bridge was so arranged by means of fixed wedges under its floor, that the side of the former was always vertical. This side was about 15 inches high, with its top, a straight edge. Parallel lines were drawn vertically across the side and spaced on 0.1 foot centers. The measuring fork proper consisted of a long-handled Tee square with the top of the Tee about 12 inches long. Into this head were driven headless nails on 1½ inch centers. The points of these nails were rounded and were each made to protrude exactly the same distance from the head of the Tee. The handle of the Tee was graduated to 0.01 of a foot.

As the experiments progressed, the principal modifications made in the original flume, aside from the method of measuring the depths, were the substitution of,

1. A rounded approach to the expanding flume, in place of a sharp entrance.

2. The erection of a platform in the stilling chamber at the elevation of the approach to the expanding flume and extending across the chamber from the baffle wall to the flume entrance.

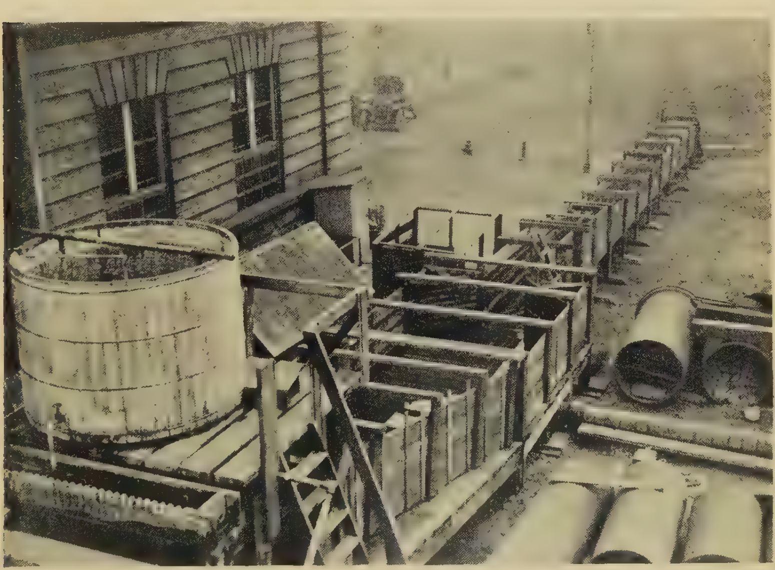

FIG. 3. EXPERIMENTAL FLUME

3. The cutting down of the baffle wall to the elevation of this platform.

4. The construction of a gradual approach to the 3-foot outlet flume, and

5. The changing of the chemical application from a point just before the baffle, to the entrance to the expanding flume.

Most of the chemical mixing experiments as well as the hydraulic studies were made on this modified apparatus.

Water for the hydraulic experiments was chlorinated raw Lake Erie water, and was supplied by a 30 million gallon steam turbine driven centrifugal pump. The water entered the stilling chamber through a 36-inch pipe and was measured by a Venturi meter with a mercury manometer.

Another view of the original apparatus is shown on figure 3.

OBJECT OF EXPERIMENTS

In the study of the various hydraulic phenomena, their practical application to water purification plant design was the object sought. The measurements made and the deductions drawn have been found to be accurate as has been proved by the results obtained by the operation of the three large hydraulic jump mixing flumes, incorporated in the construction of Cleveland's new 165-m.g.d. filter plant.

HYDRAULIC DATA

During the course of the experiments, an attempt was made to study the action within the jump itself, by means of the Pitot tube. This attempt was unsuccessful in so far as quantitative values were concerned, but was highly profitable from the standpoint of qualitative results. It was found that, at various points, the velocity would gradually build up to a maximum, then, with apparently no change in the flow conditions, the Pitot tube would suddenly indicate a reversal of the direction of the flow, building up again to the maximum velocity. This phenomenon would frequently be repeated and for no observed causes. There was apparently no regularity about its action. The increase in velocity was sometimes slow and sometimes rapid. At times, the Pitot tube would indicate a flow in one direction, at the maximum velocity, for a period of five minutes or more; at other times, as soon as the flow in any direction had reached its maximum velocity, it would be suddenly reversed, indicating that there were many forces in operation which caused numerous currents and counter-currents within the jump and which produced a violent agitation and commingling of the water, all of which contributed to remarkably effective mixing action. Some idea of the multiplicity of currents and counter-currents existing in the hydraulic jump may be obtained from figures 4 and 5.

On figure 6 is shown one of the three 55 m.g.d. capacity hydraulic jumps at Cleveland's Baldwin Filtration Plant. These large flumes were designed on the basis of the experiments herein described. It shows the practicability of designing and building mixing flumes of this type of any desired capacity.

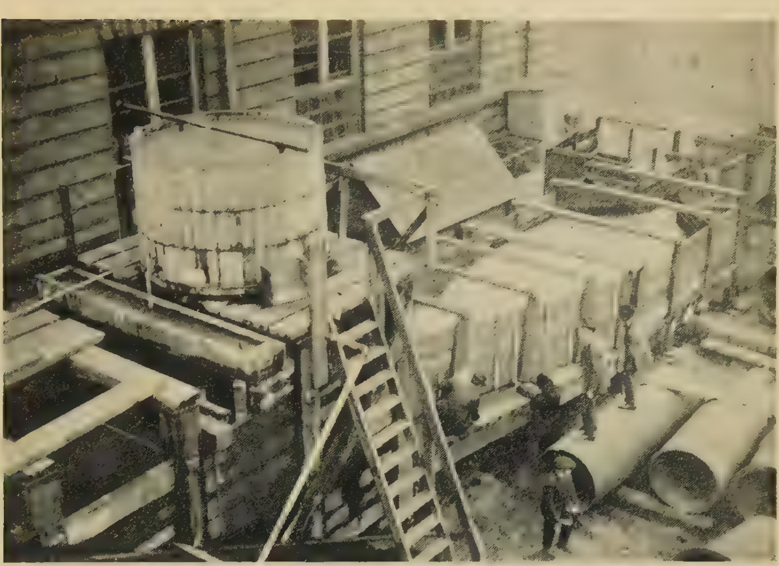

FIG. 4. TURBULENCE OF HYDRAULIC JUMP

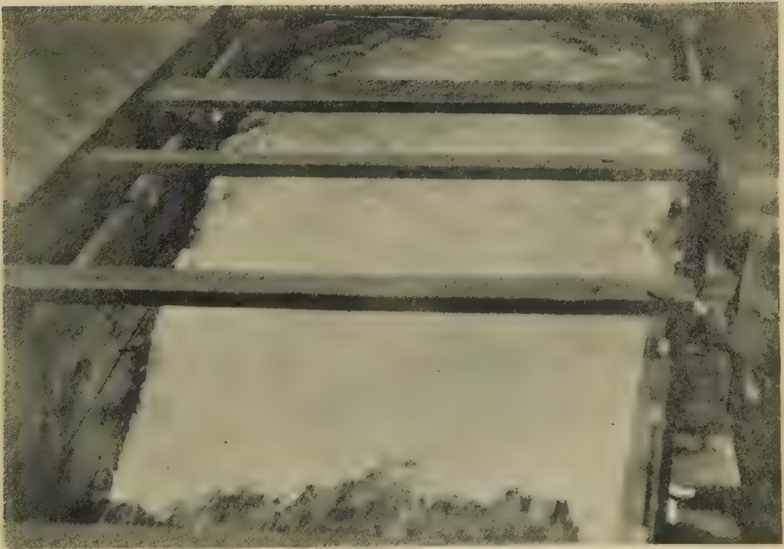

FIG. 5. CLOSE-UP VIEW OF TURBULENCE OF HYDRAULIC JUMP

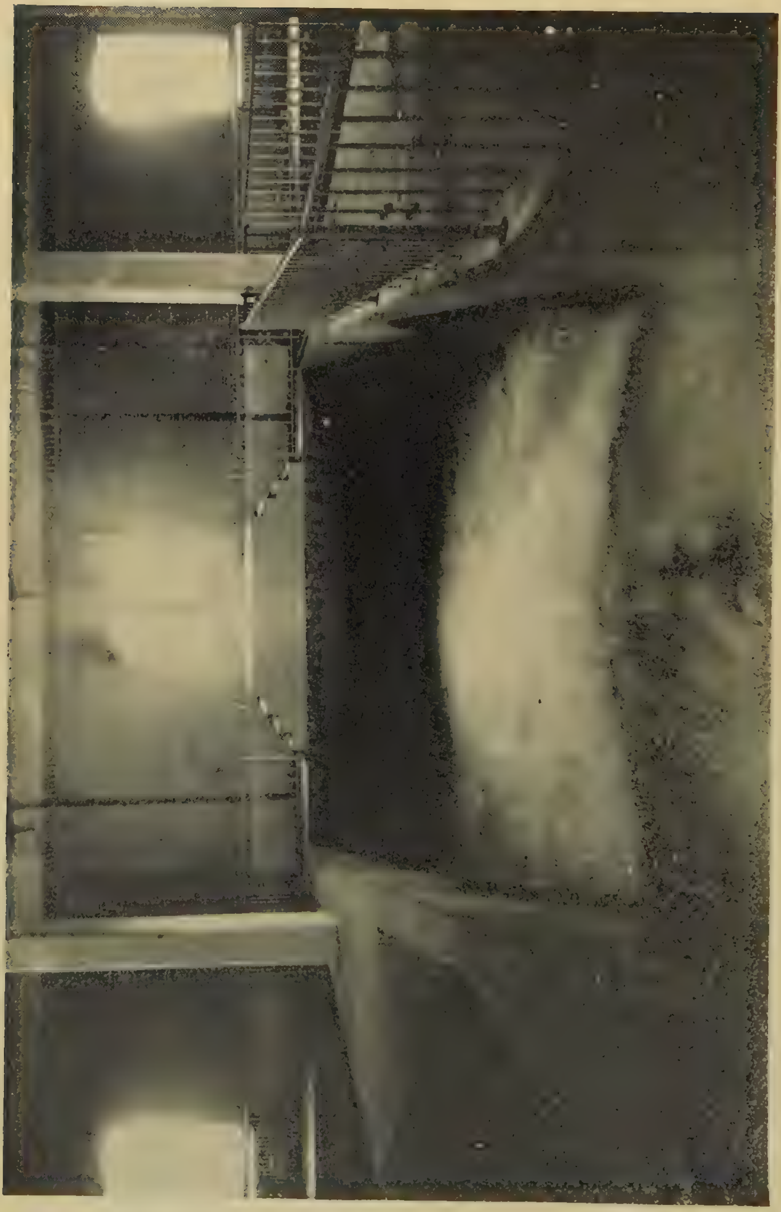

Fig. 6. One of the Three 55 m.g.d. Capacity Hydraulic Jumps at Cleveland's Baldwin Plant

The first set of hydraulic data was obtained from the flume as originally constructed. These observations consisted of gauge readings to determine the depths in the expanding flume, and in the water after the jump. It was especially desired to obtain the depth just before the jump and after a part of the experiments had been run and the data plotted, it was realized that the attempt to interpret the depths between the gauges within the vicinity of the jump was not satisfactory, and that other means of securing this information would have to be evolved. About this time, closer scrutiny was given to the appearance of the water in the expanding flume, and, as a result, the accuracy of the glass gauge measurements was questioned. The forked gauge apparatus was then devised and certain preliminary sets of readings taken with it. It was found, as was expected from appearances, that the depth of water varied at any given section across the expanding flume. There were apparently several conditions in this flume which accounted for the above mentioned variations in levels. These conditions were as follows:

1. Slight inequalities in the flooring at any given cross section due to the planking having been laid at right angles to the line of flow of the water.
2. Increased friction at the outer edges of the flowing stream due to the sides of the expanding flume.
3. Vertical uprights, which were required for structural reasons, in the stilling chamber up stream from the entrance to this flume, and which caused eddies, and
4. A sharp entrance to the throat of the flume.

All of these conditions could either be entirely obviated or minimized in any permanent structure. In the experimental flume, however, the first three conditions could not be changed, but the fourth was easily remedied and the change to the curved approach was made. The inability to make these changes in the experimental flume did not appreciably affect the results obtained, as we were enabled to take a sufficient number of readings of depths of water so that the average results were extremely accurate.

The exit end of the flume was wider than the flume connected to it used to convey the water to the lake, and therefore produced eddies at this point. This resulted in a somewhat greater depth of water here than was desirable, and it was in some measure reduced by the widening of the conveying flume to the full width of the exit end of the hydraulic jump flume and gradually reducing it, in a distance of about 22 feet, to the original width. This last change enabled a study to be made of flow conditions through a gradual contraction based on the theory of "maximum flow." This theory is exemplified by Lane in his "Flow of Water Through Contractions," published in the Transactions of the American Society of Civil Engineers, volume lxxxiii. According to Lane, this theory is applicable to a channel with a level floor only. However, with such small differences of floor elevations as existed, by utilizing Bernouilli's Theorem to take these differences into consideration, it was found practically to apply to the case in hand.

Up to this time in our experiments, no satisfactory way had been found to calculate the depth of water at the entrance to the expanding flume. With the installation of the gradual approach thereto, the experiments of Lane were again utilized, and on the basis of the "theory of maximum flow," the control depth at the entrance to the expanding flume was established. Another method of determining this depth was explained by Julian Hinds, in his article "The Hydraulic Jump and Critical Depth in the Design of Hydraulic Structures," published in the Engineering News Record of November 25, 1920.

From this time on, there were two main objectives, from the standpoint of the hydraulics of the jump; namely, (1) to determine how closely the computed and actual surface curves in the expanding flume checked, and (2) to locate the jump for any given depth of tail water.

The method of determining the surface curves, experimentally, was as follows: a dozen stations were located at intervals along the expanding section of the flume, being closer together near the entrance. These latter were required in order to study the changes which took place immediately after the water entered this flume. The vertical side of the movable bridge was placed at a given station at which it was desired to secure depth readings. The forked gauge was then held firmly against this side and gradually lowered in line with the 0.1 foot markings on its face until the points on the gauge just touched the water surface. Owing to the irregularity of the water, the object was to secure an average level and this was readily accomplished by watching the points as each one cut the surface of the swiftly moving water. When half of the points were in contact with the water surface, the gauge was read on line with the straight edge at the top of the bridge. The forked gauge was then moved

Main

across the flume to another location, and a similar proceeding followed. This method was continued at four to six points in the width of the flume, depending on the station at which the bridge was set. This process was repeated until a total of from 20 to 25 readings had been taken at a given cross section. The location of the bridge was then accurately determined with reference to the entrance to the expanding flume, and was then moved to another station where similar measurements were secured with the forked gauge and the bridge similarly located with reference to the entrance to the expanding flume. The bridge was successively moved to each of the stations and the water surface measurements taken as before. After all surface measurements had been secured, the flow of water was cut off and measurements similarly made, at the various stations, to the floor of the flume. By differences the water depths were obtained. A special station was located in every case just before the jump. To avoid any differences in the deflection of the bridge, the same individual who took the water surface measurements always took the floor measurements also.

In order to compute the surface curve, the depth of water at the beginning of the slope of the expanding flume is secured from the formula:

$$Q = 3.09\, WH^{\frac{3}{2}}$$

which formula is derived from the theory of "maximum flow." In this formula,

Q = cubic feet per second.
W = width in feet at the entrance to the flume.
H = total energy head, namely, static plus velocity head.

The depth will, in every case, equal $\frac{2}{3}$ of the value of H. While the depth thus obtained is not strictly applicable to the point where the expanding flume begins to slope, practically this value can be used and the discrepancy soon disappears in the first few computations in the expanding flume itself. Having found a starting point from the above value, the remaining points of the surface curve can be obtained from the depths computed by means of Bernouilli's Theorem, which may be written:

$$\left(Y_1 + \frac{v_1^{2}}{2g}\right) - \left(Y_2 + \frac{v_2^{2}}{2g}\right) = \frac{1}{c^2}\frac{v^2}{r}$$

in which Y_1 = elevation of water at the known section.

$\frac{v_1^2}{2g}$ = velocity head at the known section.

Y_2 = elevation of water at the section to be ascertained.

$\frac{v_2^2}{2g}$ = velocity head at the section to be ascertained.

l = distance between the sections measured along the slope.

v^2 = average of velocities at the two sections.

r = average of the hydraulic radii at the two sections.

c^2 = Kutter's coefficient based on the average "r."

In using this equation, it is necessary first to assume a depth at the section at which it is desired to secure a point on the surface curve. This depth once assumed, for any given quantity of water, the velocity head at the section can be determined, as well as the value of the friction loss as represented in the second part of the equation, namely, $\frac{lv^2}{c^2r}$. If, with the depth assumed, the equation does not balance, a new depth must be assumed and the process repeated until the two sides of the equation are equal. While this process may seem laborious, familiarity with the problem soon enables one to assume correct depths with remarkable facility. The agreement between the theoretical and actual surface curves is shown on figure 7.

Having obtained the surface curve in the manner just outlined, the next step, in carrying through the problem, requires the location at which the hydraulic jump takes place. For any given quantity of water, and any given type of flume, this location is a function of the depth of water at the foot of the slope. Theoretically, for any given depth of tail water, the location of the jump can be found by,

1. Starting with this depth and computing the tail water curve in a manner similar to that in which the surface curve was computed, with the exception that the second part of the equation may be omitted because the friction loss is so small as to be negligible, and

2. Finding the point at which this tail water curve intersects the locus of the jump, the latter being a curve which joins the various points designating the height to which the water would jump at the respective sections at which these points are located.

This height of jump, for any given section, can be obtained from the formula:

$$d_2 = \sqrt{\frac{2v_1^2\,d_1}{g} + \frac{d_1^2}{4}} - \frac{d_1}{2}$$

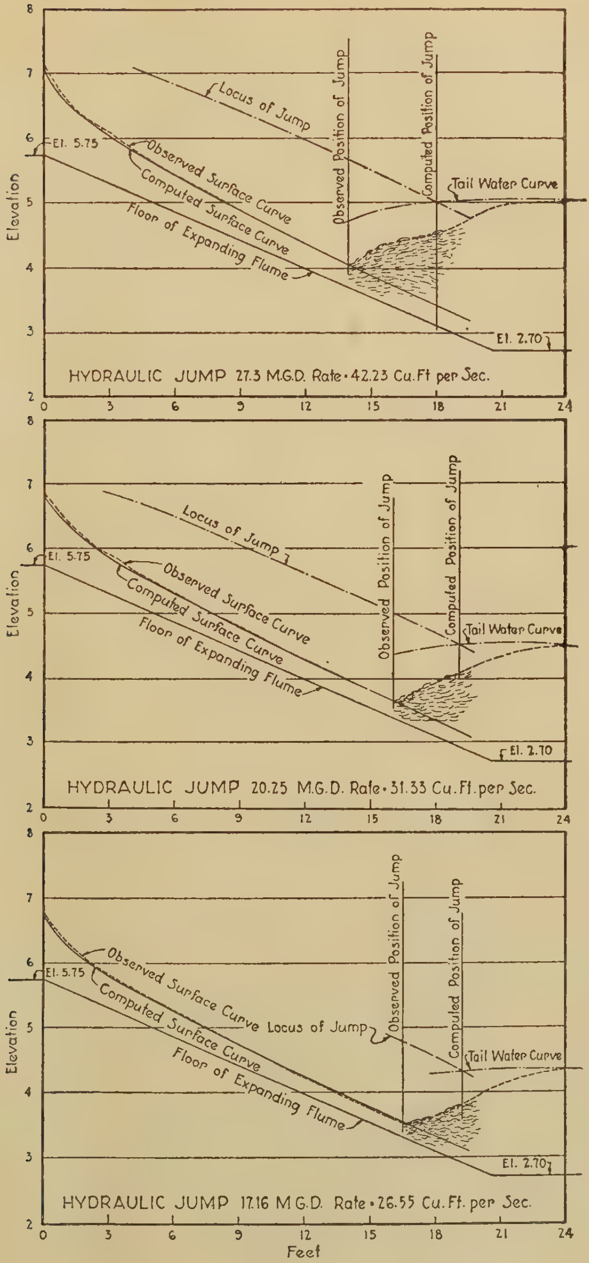
Locus of Jump
Observed Position of Jump
Computed Position of Jump
El. 5.75
Observed Surface Curve
Computed Surface Curve
Floor of Expanding Flume
Tail Water Curve
El. 2.70
HYDRAULIC JUMP 27.3 M.G.D. Rate • 42.23 Cu. Ft per Sec.
HYDRAULIC JUMP 20.25 M.G.D. Rate • 31.33 Cu. Ft. per Sec.
HYDRAULIC JUMP 17.16 M.G.D. Rate • 26.55 Cu. Ft. per Sec.
Elevation
2
3
4
5
6
7
8
Feet
0
3
6
9
12
15
18
21
24

FIG. 7

in which d_2 = depth of water immediately after jump.
d_1 = depth of water just before the jump.
v_1 = velocity of water just before the jump.

From our experiments, it was found that the jump occurred, in every case, higher up the slope than is given by the theoretical location and, therefore, it is necessary to apply a correction factor before this theoretical position can be utilized. Inasmuch as the use of the jump in connection with filtration plant design requires, not its location for any given tail water depth, but rather the tail water depth for any fixed location, the actual process consists, in,

1. Determining the height of jump for any given section at which it is desired to have the jump take place,
2. Computing the tail water curve, starting with this particular height of jump; and
3. Applying a coefficient to the theoretical depth of water at the foot of the slope as obtained from the tail water curve.

This coefficient for the particular type of expanding flume used in our experiments is shown on figure 8. As may be seen, the coefficient is some function of the velocity before the jump and, therefore, the coefficient to apply to the theoretical depth of tail water may be found by entering the chart with this velocity, finding where it crosses the curve and then following down to the coefficient.

LOSS OF HEAD

For its use in filtration plant design, it is necessary to investigate the hydraulics of the jump for the maximum height of tail water as backed up from the highest water level in the coagulation basins, under conditions of minimum as well as of maximum flow through the flume. It is also necessary to keep in mind that, as a result of our experiments, it was found advisable that the jump should not be made to take place under any condition, closer to the throat of the flume than a minimum of about 3 feet or at a section having a velocity of less than about 9 feet per second. Under these conditions, the loss of head in the hydraulic jump mixing device is from 0.75 to 1.00 foot. This is the loss which would be produced when the water in the coagulation basin is at the overflow. Inasmuch as the normal operating level is from 0.75 to 1.00 foot below this point the total loss of head will vary from 1.5 to 2.0 feet.

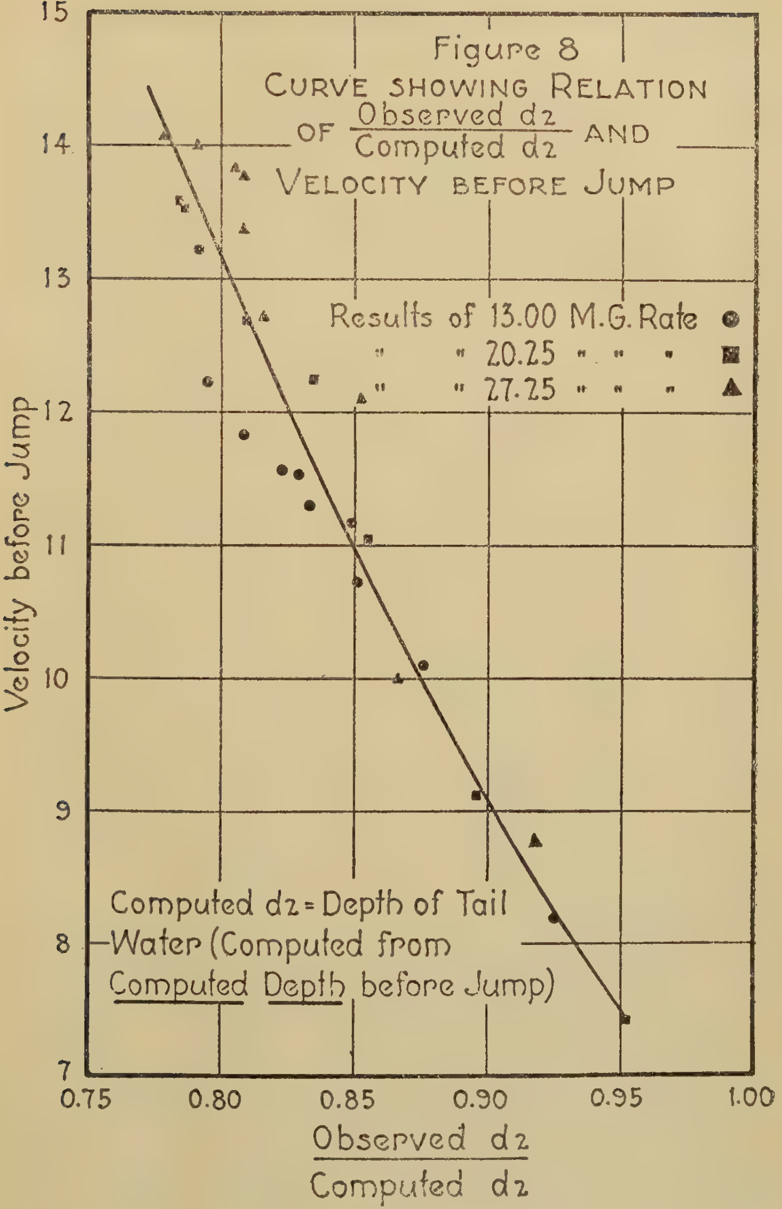
Figure 8
CURVE SHOWING RELATION OF Observed d2 / Computed d2 AND VELOCITY BEFORE JUMP
Results of 13.00 M.G. Rate ●
" " 20.25 " " " ■
" " 27.25 " " " ▲
Computed d2 = Depth of Tail Water (Computed from Computed Depth before Jump)
Velocity before Jump
15
14
13
12
11
10
9
8
7
0.75
0.80
0.85
0.90
0.95
1.00
Observed d2 / Computed d2

FIG. 8

EFFECT OF HYDRAULIC JUMP ON REACTIONS OF ADDED CHEMICALS

The addition of solutions of sulphate of alumina, and of suspensions of lime to the water just prior to its entrance to the throat of the flume was studied in order to determine the thoroughness of the mixing action of the hydraulic jump, and the rapidity and completeness of the chemical reactions involved. The introduction of a solution of sulphate of alumina was first tried. After starting treatment, samples were collected every five minutes for a period of one-half hour. The results obtained are shown in table 1.

TABLE 1

Showing the completeness of the chemical reaction effected by the hydraulic jump

TEST NUMBER	RATE OF FLOW	DEPTH OF TAIL WATER	LOCATION OF JUMP FROM FLUME ENTRANCE	ALUMINUM SULPHATE ADDED	ALKALINITY OF RAW WATER	ALKALINITY OF TREATED WATER PARTS PER MILLION				
						Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
	m.g.d.	*feet*	*feet*	*grains per gallon*						
1	13	1.68	15.50	1	94	86	86	86	84	84
2	20.25	2.02	14.95	1	94	86	86	86	86	84
3	27.25	2.45	13.47	1	94	86	86	86	86	86
4	13	2.63	9.00	1	94	86	86	86	86	86
5	20.25	2.87	9.39	1	94	86	86	86	86	86
6	27.25	3.09	9.39	1	94	87	88	88	88	87

The reaction between the alum and the alkalinity of the water, like all ionic reactions, is completed in an immeasurably short space of time. The time of passage through the jump and pool immediately beyond, where the samples were taken, was about 30 seconds. As the theoretical reduction in alkalinity for each grain of alum per gallon added is 7.7 parts per million, it is apparent that the reaction is complete and that the mixing has been thorough. The rates of flow, the position of the jump, and the depth of the tail water are all given in the table to show that these variations do not affect the thoroughness of the mixing action, nor the completeness of the chemical reaction.

The application of a milk of lime to a water to effect a reduction in its natural lime content offers as severe a test of the thoroughness of mixing and reaction velocities as is found in water purification problems. The milk of lime was applied to the water just before it entered the throat of the flume. Two samples of the treated water were taken beyond the jump at the entrance to the discharge flume every five minutes after starting to add the milk of lime. One of each pair of samples was tested immediately and then allowed to stand, while the other was shaken vigorously at frequent intervals for a period of one hour before being tested. Each pair of samples was tested at hourly intervals, thereafter, for several hours, and ,finally on the following morning. All samples were filtered before testing. The results are shown in detail in table 2.

It will be noted that, at the expiration of one, two, three or even twenty-four hours, there is no practical difference in the residual alkalinity of the pairs of samples of the treated water, no matter whether the samples had received additional agitation after passing through the jump or not. There was a gradual reduction in the total alkalinity of both samples of about ten parts per million, at the expiration of twenty-four hours, which is entirely normal, and which is obviously independent of the difference in the degree of agitation employed. This proves that the mixing afforded by the hydraulic jump had produced a thorough mingling of the water being treated with the applied milk of lime and that chemical reactions were completed in a normal manner.

RELATION OF MIXING ACTION OF HYDRAULIC JUMP TO COAGULATION

The efficiency of the hydraulic jump as a mixing device having been proved, the question arose as to what affect it had on the speed of formation of aluminum hydroxide floc, on the size of the floc, on its settling properties, and on its retentive capacity for bacteria when applied to a filter. The influence of additional agitation following the passage of the treated water through the jump was studied largely by means of bottle experiments and modifications of the large flume so that smaller quantities of water could be handled.

The formation of aluminum hydroxide by adding alum to an alkaline water has been intensively studied by many investigators during the past seven or eight years and many phases of the phenomena of coagulation are better understood than when the experiments summarized in this paper were undertaken in 1920 and 1921.

TABLE 2

Results of lime treatment at hydraulic jump flume¶

SAMPLE NUMBERS	DATE	RATE OF FLOW OF WATER M. G. PER DAY	GRAINS PER GALLON OF CaO	ALKALINITY OF RAW WATER		ALKALINITY OF TREATED WATER IMMEDIATELY AFTER SAMPLING				ALKALINITY OF TREATED WATER ONE HOUR AFTER SAMPLING				ALKALINITY OF TREATED WATER TWO HOURS AFTER SAMPLING				ALKALINITY OF TREATED WATER THREE HOURS AFTER SAMPLING				ALKALINITY OF TREATED WATER FOLLOWING DAY			
				Total	Mono.	Total	Bicarb.	Caust.	Mono.	Total	Bicarb.	Caust.	Mono.	Total	Bicarb.	Caust.	Mono.	Total	Bicarb.	Caust.	Mono.	Total	Bicarb.	Caust.	Mono.
*3	December 12, 1919	27.5	3.34	90	T	116	0	34	82	52	0	16	36	50	0	10	40	50	0	10	40	42	0	10	32
†3A	December 12, 1919	27.5	3.34	90	T					50	0	10	40	48	0	12	36	50	0	10	40	46	0	14	32
*7	December 30, 1919	27.5	3.26	90	0	134	0	2	132	54	6	0	48	46	10	0	36	42	10	0	32	40	12	0	28
†7A	December 30, 1919	27.5	3.26	90	0					50	0	10	40	44	4	0	40	44	4	0	40	40	0	0	40
*8	December 30, 1919	27.5	3.26	90	0	118	0	6	112	50	6	0	44	46	10	0	36	46	6	0	40	38	6	0	32
†8A	December 30, 1919	27.5	3.26	90	0					52	0	12	40	44	0	0	44	44	4	0	40	40	4	0	36
*9	December 30, 1919	27.5	3.26	90	0	118	0	18	100	50	6	0	44	48	4	0	44	44	8	0	36	40	8	0	32
†9A	December 30, 1919	27.5	3.26	90	0					48	0	8	40	46	0	6	40	44	4	0	40	36	12	0	24
*10	December 30, 1919	27.5	3.26	90	0	114	0	14	100	52	16	0	36	48	12	0	36	46	6	0	40	34	30	0	4
†10A	December 30, 1919	27.5	3.26	90	0					48	4	0	44	46	10	0	36	42	6	0	36	32	32	0	0
*11	December 31, 1919	27.5	3.17	92	T	148	0	20	128	48	8	0	40	46	6	0	40	46	2	0	44	42	0	2	40
†11A	December 31, 1919	27.5	3.17	92	T					50	0	2	48	42	2	0	40	50	0	2	48	46	0	14	32
*12	December 31, 1919	27.5	3.17	92	T	136	0	16	120	54	2	0	52	46	6	0	40	44	8	0	36	42	0	2	40
†12A	December 31, 1919	27.5	3.17	92	T					44	12	0	32	46	6	0	40	40	4	0	36	32	12	0	20
*13	December 31, 1919	27.5	3.17	92	T	142	0	2	140	46	10	0	36	40	12	0	28	40	24	0	16	40	0	0	40
†13A	December 31, 1919	27.5	3.17	92	T					50	2	0	48	44	4	0	40	40	4	0	36	38	2	0	36

*14	December 31, 1919	27.5	3.17	92	T	130	0	6	124	46	18	0	28	44	16	0	28	44	8	0	36	40	4	0	36
†14A	December 31, 1919	27.5	3.17	92	T					44	8	0	36	46	10	0	36	44	8	0	36	36	4	0	32
*15	January 7, 1920	29.5	3.87	94	T	116	4	0	112	56	0	12	44	42	6	0	36	52	0	0	52	50	0	6	44
†15A	January 7, 1920	29.5	3.87	94	T					54	0	6	48	46	2	0	44	48	4	0	44	40	0	4	36
*16	January 7, 1920	29.5	3.87	94	T	122	0	2	120	52	0	0	52	46	2	0	44	48	4	0	44	36	4	0	32
†16A	January 7, 1920	29.5	3.87	94	T					50	0	2	48	44	8	0	36	46	6	0	40	40	0	8	32
*17	January 7, 1920	29.5	3.87	94	T	116	0	8	108	56	0	8	48	46	10	0	36	54	2	0	52	44	0	4	40
†17A	January 7, 1920	29.5	3.87	94	T					52	0	4	48	38	10	0	28	54	0	2	52	38	2	0	36
*18	January 7, 1920	29.5	3.87	94	T	126	0	10	116	50	2	0	48	44	4	0	40	50	2	0	48	36	4	0	32
†18A	January 7, 1920	29.5	3.87	94	T					44	4	0	40	44	8	0	36	50	0	6	44	40	0	8	32
*19	January 13, 1920	27.5	2.45	94	T	122	10	0	112	54	10	0	44	48	16	0	32	50	14	0	36	42	10	0	32
†19A	January 13, 1920	27.5	2.45	94	T					50	22	0	28	48	20	0	28	48	20	0	28	42	10	0	32
*20	January 13, 1920	27.5	2.45	94	T	120	12	0	108	56	20	0	36	56	20	0	36	52	20	0	32	42	14	0	28
†20A	January 13, 1920	27.5	2.45	94	T					52	20	0	32	48	20	0	28	48	20	0	28	42	18	0	24
*21	January 13, 1920	27.5	2.45	94	T	120	12	0	108	56	20	0	36	54	22	0	32	50	22	0	28	44	16	0	28
†21A	January 13, 1920	27.5	2.45	94	T					50	14	0	36	50	22	0	28	48	20	0	28	42	14	0	28
*22	January 13, 1920	27.5	2.45	94	T	126	6	0	120	56	20	0	36	52	24	0	28	50	26	0	24	42	22	0	20
†22A	January 13, 1930	27.5	2.45	94	T					54	22	0	32	52	28	0	24	50	26	0	24	42	22	0	20
‡				92	T	125	0	3	122	52	0	1	51	47	1	0	46	47	1	0	46	41	7	0	34
§				92	T					50	4	0	46	46	2	0	44	46	5	0	41	40	3	0	37

* All samples without a letter show results of mixing effect of Jump only.

† All other samples were given one hour additional mixing.

‡ Average of samples marked thus (*)

§ Average of samples marked thus (†)

¶ All results in parts per million.

It is now known that the controlling factor of coagulation is the hydrogen-ion concentration of the water, and that the influence of dissolved salts and organic matter may materially affect this concentration.

Our observations were confined to the comparison of samples of Lake Erie water treated in different ways in order to study the effect of varying degrees of agitation on the size of the floc and on the length of time required for it to form. Obviously, no good measure of floc formation was or is now available, and much depends on personal judgments. The general conclusions reached from a large number of experiments are, however, as follows:

1. Violent agitation to produce thorough and rapid mixing of the applied chemical and the water to be treated is the first requisite for chemical reaction preparatory to proper flocculation. This effect is produced by the hydraulic jump.
2. The time required to produce such mixing is probably less than 30 seconds or the time required for the passage of the water through the jump and the pool beyond.
3. Continued violent agitation following the mixing action of the jump is detrimental to floc formation.
4. Gentle agitation produced by a velocity of flow from 0.75 to 1.00 foot per second hastens floc formation and produces a good aggregation of the finely divided particles in about 5 to 6 minutes. Velocities below these figures require a longer time for floc formation; velocities above these figures may hinder floc formation if continued too long.
5. Slightly baffled channels so designed with relation to the flow as to produce the above velocities for the period mentioned above will provide the requisite conditions for rapid flocculation.
6. Bacterial removals by sand filtration of water mixed by the hydraulic jump and passed through a settling chamber, prior to filtration, showed equally as good results as the same water mixed in a baffled mixing chamber and settled.

The studies made by the writers were carried on with Lake Erie water, which is one which has practically no color, and very low turbidity. Its alkalinity is rather high and consequently its hydrogen-ion concentration (pH. 7.8 to 8.1) low. The amounts of alum used were in most cases 1 grain per gallon or less, and, in consequence, the hydrogen-ion concentration was raised but little and certainly was very far from the optimum concentration for the rapid formation of aluminum hydroxide floc which later investigators found desirable. The use of the hydraulic jump on other types of water has, usually, proved the soundness of the deductions drawn from our experiments. It may be that some modification of time and velocity factors, following the passage of turbid or softened waters through the jump, will be required in some cases; but, in general, it is believed that these variations will not be markedly different from those found in this investigation.

GENERAL CONCLUSIONS

The general conclusions as a result of this work may be summarized as follows:

1. The hydraulic jump is an extremely effective means for mixing chemicals with water to be purified.

2. The mixing effect is produced with great rapidity and with remarkable thoroughness.

3. The chemical reactions cannot take place until the chemical or chemicals are in solution and are diffused throughout the water to be treated, which latter is so many times larger in volume than the reagent solutions being applied, that the value of a rapid and thorough method of mixing is obvious.

4. The energy relations of the hydraulic jump have been studied by several investigators and the principles involved are sufficiently well understood so that it is possible to design and construct a flume in which the "jump" may be produced and controlled within comparatively narrow limits.

5. The loss of head through such a "jump" may be made as low, if not lower, than is produced in any of the conventional, baffled, mixing chambers, hence its practicability and economy from the hydraulic standpoint.

6. The structure in which the jump may be produced is simple, requiring comparatively little space and a small amount of material for its construction. On this score its cost is far less than that of the conventional, baffled mixing chamber.

7. The jump conveniently lends itself, after thorough mixing of the chemicals with the water, to any character of structure desired beyond the "jump" to facilitate coagulation and sedimentation.

DISCUSSION

Wm. Gore:[5] This paper gives an interesting and valuable account of experiments relating to an important hydraulic principle and of its application to the art of water purification. The authors are to be highly complimented on the excellence of their work which forms a valuable addition both to the science of hydraulics and to the art of water purification.

The hydraulic jump is essentially an open sloping channel terminating in a still or dead water basin. The high velocities generated in the rapid fall of any liquid passing down the channel is dissipated by shock in the still water basin. The principle involved is encountered in nature in the tidal bore and the device has been used largely in reservoir overflows and drop discharges in sewers. While the present paper gives detailed studies of the hydraulic principle it shows it to be an excellent mixing device by reason of the turmoil which takes place in the so called still water basin.

It should however be pointed out that any device which produces shock in a moving body of water such as an obstruction in a water main by a partially closed valve or orifice is or can be made equally or almost equally as good a mixing device as the hydraulic jump, the difference if any being in the aeration in the jump, but the potential energy is dissipated by shock or turbulence in the same way in both cases. The obstructed flow in a pipe is well known as a mixing device in the art of water purification.

In places where a centrifugal pump is in use as a lifting device at the purification plant it would appear to afford the logical means for mixing the chemicals with the water, particularly if the chemicals are added at the eye or suction inlet of the pump. A centrifugal pump lifting water 20 feet with an efficiency of 80 per cent dissipates as much energy by turmoil in the water as in an hydraulic jump with a drop of 4 feet. This turmoil can and is being successfully used for mixing purposes in the art of water purification. The operation of mixing as in the case of the hydraulic jump takes place so quickly that there is little time for chemical changes and local coagulation to take place previous to complete mixing.

Almon L. Fales:[6] The speaker would like to say a word of appreciation of the work of Levy and Ellms in developing the hydraulic jump as a mixing device. It is certainly an effective device for this purpose.

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[5] Of Gore, Nasmith and Storrie, Toronto, Can.

[6] Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

Along the line of what Mr. Gore has said I would like to state that we have found the centrifugal pump to be an excellent mixing device when the coagulant is added close to the pump suction.

In several cases where it has been necessary to pump industrial wastes which required treatment with alum, we have introduced the alum solution at the suction of the pump with very satisfactory results. We have also had experience in pumping wastes where the alum had been applied some distance ahead of the pump, so that the floc had formed before pumping, and in such cases the floc was completely broken up by the centrifugal pump.

I have in mind one instance where tannery wastes treated with alum, had flocculated to such an extent that, if the wastes were allowed to stand and settle, they would become very clear, whereas after pumping the treated wastes with a centrifugal pump there was no indication that a coagulant had been added. The wastes were returned to their original turbid, colloidal condition. It is very important to introduce the alum close to the suction of the pump, so as to get the mixing immediately and the flocculation afterwards.

J. W. Ellms:[4] The chemicals used in water purification processes are applied as a solution or as a suspension. The volume of the liquid in which they are dissolved or suspended is relatively very small compared with the volume of the water to which they are added. The need for a thorough mixing of the two liquids is obvious, since no chemical reactions, and the physical changes resulting therefrom, can take place unless there is a commingling of the two liquids. The larger the volume of the water to be treated, the more difficult it becomes to bring about a thorough and rapid mixing. In the earlier and smaller plants that were built probably little attention was given to this feature of the process; but when the building of larger plants became more common, it was found necessary to provide for a more complete incorporation of the chemicals with the water. This explains, it is believed, how mixing channels or chambers became a common feature of design of water filtration and softening plants.

In order to prevent sedimentation in the channels, it was necessary to give the water a velocity that would insure the carriage of all the sediment through the channels into the settling basins. To effect this result long and narrow channels were constructed, and to prevent a possible stratification and to insure a positive mixing of the top and bottom layers of water over and under baffles were introduced into the design. The final result was a costly and cumbersome structure.

The hydraulic jump mixing flume was designed to overcome the objectionable features of the conventional around-the-end and over and under baffled mixing chambers. It accomplishes the purpose for which it was designed as explained in this paper. It mixes within less than one minute a very small volume of chemical solution with the relatively very large volume of water being treated; it produces a uniform diffusion of the chemical solution; it thoroughly aerates the water as it passes through the jump; it is extremely flexible in adapting itself to variations in the rate of flow of the water; it uses no more head, if as much, than is commonly required in the usual mixing chamber; and it can be produced in a small and comparatively inexpensive structure. It is being successfully used in the purification of colored, turbid and clear waters.

The hydraulic jump flume is a device for mixing. It is not a panacea for those errors of design which give rise to improper periods of sedimentation or coagulation; or for those obscure problems, such as imperfect flocculation and its relation to hydrogen-ion concentration, to the buffer effects of salts or to the varying characteristics of the colloidal state of the suspended matter that may be present in the water. The solution of these difficulties must be sought for elsewhere than in the simple and necessary intermingling of the reacting chemicals and the water being treated.

It is quite true, as the previous speakers have pointed out, that rapid mixing may be effected by discharging the chemical solution into the raw water pumps. However, the rapidly formed floc must be subjected to such violent treatment either within the pump itself (especially where centrifugal pumps are used), or in the force mains beyond the pump, that it is liable to be badly broken up. Once the floc is torn to pieces, its value as a coagulating agent is practically lost. That such a method of mixing has not been more generally used would seem to indicate that difficulties of the nature of those named above were the cause, and that if, as claimed by the previous speaker, it has ever been successful there must have been conditions peculiar to those particular installations or to the type of water being treated, which made it a practical method.

INCREASING THE WATER SUPPLY OF WASHINGTON, D. C.[1]

By J. E. Curtis[2]

That the city of Washington is increasing its water supply is not nearly so remarkable as that it has not increased it since the present supply was built. A brief mention of the present system, because of its intimate relation with the new system now being constructed, may be of interest.

Back in 1859 the first water was turned into the conduit to supply a population of 58,000. The estimated daily capacity of the aqueduct was 67½ million gallons or sufficient to give every being in the city a quantity of water that even some of our moderns, accustomed to waste it, could not possibly have consumed. The vision of the engineers who built this system is further emphasized by the fact that, at the time of its completion, the 9-foot diameter supply conduit was reduced to a 12-inch diameter main to supply the entire city, and the same conduit now supplies a population increased over 800 per cent.

The present system consists of a dam across the Potomac river, a circular masonry conduit 9 feet in diameter and 12 miles long having a fall of 9 inches to the mile, 3 storage and sedimentation reservoirs, a tunnel 4 miles long under the city, a pumping station, a slow sand filtration plant of 29 one-acre beds and a clear water reservoir. In addition there are the distribution mains, pumping stations and high service reservoirs. The water supply and purification works are vested in the Chief of Engineers, United States Army, while the distribution is vested in the city government.

After various projects for new supplies were investigated Congress, in 1921, appropriated funds to begin the construction of an increased water supply. This project takes its supply from the Potomac river through a new intake gate house about 100 feet above the present intake at Great Falls, Md.

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[1] Presented before the Buffalo Convention, June 8, 1926.

[2] Superintendent, Washington Aqueduct, Washington, D. C.

The first 2800 feet of the new conduit are in tunnel to a point where it approaches the old conduit. Here a drop shaft, an under crossing of the old conduit, and a rise shaft form the beginning of about 8 miles of conduit paralleling, at about 30 feet center to center, the present conduit. Since the old conduit was built as nearly as practicable to a contour it follows that both it and the new one consist of a large number of curves and tangents. The conduit is horse shoe shaped, 10 feet wide by 10 feet high, with a waterway of 79 square feet. It is unreinforced for the greater part of its length, but there are several short sections where it was impossible to place a backfill on the down hill side and these sections have been heavily reinforced. The conduit was not designed for, or will it operate under, a head, but to increase its strength it is covered with about 3 feet of backfill over the crown of the arch. At Cabin John Creek where the old conduit crossed on an arch bridge, for many years the longest masonry arch in the world, having a span of 220 feet, the new conduit is built as an inverted siphon following the steep slopes on either side and crossing the stream on piers. This crossing was made sufficiently strong to resist displacement should the stream become clogged between piers and overflow the siphon. The siphon is circular in section and consists of a riveted steel pipe 10 feet in diameter and $\frac{3}{8}$ inch thick surrounded on the outside with 12 inches of concrete and lined inside with 6 inches of concrete. The pipe is made from plates 7 feet wide and was fabricated and shipped in 35-foot lengths. After the entire steel pipe was erected it was bulkheaded at each end, filled with water under slightly more than the working head and the outside concrete poured. After this concrete had set the siphon was drained and the inside lining placed by means of forming. The filling with water was done to cause the pipe to take the shape it would assume when in operation and consequently not set up unusual strains in the concrete envelope. The 6-inch thickness of the concrete lining is more than is necessary for the protection of the steel pipe, but assures ample protection where a flattening of the pipe might possibly have lessened the thickness of the lining caused by the use of regular cylindrical concrete forms. At approximately equal intervals cross connection gate houses have been provided between the new and the old conduits so that sections of either may be drained for inspection or repairs.

For construction the conduit was divided into 4 sections; the intake gate house and tunnel at Great Falls; and 3 cut and cover sections, the last section including the Cabin John Siphon, the gate house at Dalecarlia reservoir, and a tunnel 800 feet long near the outlet. Construction was done by contract and the M. A. Long Company of Baltimore, Md. was the contractor for the first section and the Arundel Corporation of Baltimore, Md. was the contractor for the remaining sections. For the cut and cover sections the contractors used steam shovels for trenching and cast the excavation along the trench where it was later backfilled by the use of steam shovels. A considerable amount of excavation was hauled by trucks from the shovels and deposited over the finished concrete. The invert was placed in alternate 15-foot sections and the arch poured in sections varying from 50 to 100 feet. Portable concrete mixers were used along the edge of the trench and poured concrete directly into the arch forms on either side of the conduit in approximately level layers. The arch forming was of steel and was moved ahead on rails. All material was delivered from Washington by trucks.

The unit prices for several of the major items of the conduit were as follows:

Division No. 1

Ordinary excavation, including backfill	$1.55 cu. yd.
Rock excavation in open cut	2.80 cu. yd.
Concrete in conduit	16.50 cu. yd.

Division No. 2

Ordinary excavation, including backfill	$0.75 cu. yd.
Rock excavation in open cut	1.45 cu. yd.
Furnishing and placing sheeting and bracing	0.025 ft. b. m.
Concrete in conduit	14.10 cu. yd.

Division No. 3

Furnishing and placing steel pipe for siphon	$0.062 per lb.
Furnishing and placing reinforcing steel	0.05 per lb.
Ordinary excavation, including backfill	0.75 cu. yd.
Rock excavation in open cut	1.45 cu. yd.
Concrete in conduit	13.31 cu. yd.

The water from both the old and the new conduits empties into Dalecarlia reservoir, having an area of about 50 acres. Near the outlet of this reservoir there is being constructed an 80 million gallon per day rapid sand filtration plant, pumping station and hydroelectric power plant. For about twenty years the combined capacity of the 2 conduits will furnish an excess of water sufficient for power to pump the filtered water to the high sections of the city. For this supply 2 high service reservoirs of concrete with groined arch roofs, having a capacity of 15 million gallons each, have been built at different elevations, and concrete pressure mains laid with diameters of 36, 42 and 48 inches. Only this brief mention of the filtration plant is made since a complete description will be presented in another paper by P. O. Macqueen, Assistant Engineer, in charge of this portion of the work.

The entire project for an increased water supply is about 60 per cent completed and will cost in its entirety approximately $9,000,000.

MOSQUITO CONTROL IN RELATION TO IMPOUNDED WATER SUPPLY[1]

By J. A. Le Prince[2]

In recent years there has come about a decided change in the industrial and farm labor situations which has an important influence on the relation of malaria to that which the engineer may construct.

During the last two years some of the cotton crops of the Southwest and even as far north as Memphis are being gathered by labor from Mexico. Throughout the Mississippi Delta the negro farm tenant labor is constantly changing from one plantation to another, so that 75 per cent of the negro families move once a year.

Well conducted investigations, carried out on a large scale, indicate that it is not economically practical to control and effectively reduce malaria with a constantly shifting farm tenant population in our country by the use of quinine administration alone. Several such attempts have been made under proper medical supervision, but results are invariably unsatisfactory. Any large area which might be made free from malaria cases this year will be repopulated with new cases from elsewhere next year.

The study of this condition has caused many experienced malariologists to realize fully that malaria elimination is an engineering project as well as a medical problem. That brings up the question: What is being done by the engineering profession toward the elimination of malaria? The answer is that those who know the facts in the case have not had the necessary opportunity to place the situation before the engineering profession effectively, and that engineers as well as others have in many instances been building malaria into communities over a large section of our country without knowing they were doing so.

In connection with the impounding of waters, let me cite an instance: Last summer I was called on by a state board of health to look over a lake less than two years old. The town had impounded a stream to furnish a drinking water supply and electric light. The project was a good one and the financial results a success. However, soon after the water was impounded an outbreak of malaria appeared at the homes of the farming population living within less than a mile from the lake, and at the time of my visit a year later most of the families were down with chills and fever and expecting the city to pay them liberally for the suffering and loss of working time it had caused.

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[1] Presented before the Buffalo Convention, June 11, 1926.

[2] Senior Sanitary Engineer, United States Public Health Service, Washington, D. C.

The city officials claim they had no idea the project would cause such havoc; and the people affected say neither did they; but the town must pay.

It is evident that the engineer in charge in his preliminary surveys and estimates carefully considered all phases of the project except the malaria hazard; and that he knew nothing whatsoever about that. This is merely one illustration of what malariologists mean when they speak of building malaria in.

Before we knew what malaria was and how to prevent it, our profession placed culvert bottoms too high to allow the territory above to be effectively drained so far as malaria is concerned.

We constructed a series of borrow pits along the railroads leading to villages and towns, which increased the supply of malaria mosquitoes; and then to cap the climax we often allowed the contractors to draw their labor from communities having high malaria rates where jobs for the laboring man are harder to find.

Thus, unconsciously, the engineer was bringing increased malaria prevalence to town or village along with increased transportation facilities.

I recently had the pleasure of giving a short talk at the North Carolina Section of the American Water Works Association on the "Relation of Storage Water Supply Lakes to Malaria," which was published in THE JOURNAL (Vol. 15, No. 1, January, 1926), to which I desire to invite your attention.

During the month in which the article appeared an inquiry was sent by a prominent consulting engineer to the United States Public Health Service asking for some additional information regarding the city water supply lake then being constructed under his direction. If the engineer in the Tennessee case cited had called on his State Board of Health, the epidemic of malaria could have been prevented. The United States Public Health Service has investigated and studied the problems of malaria in relation to impounding of water for a period of ten years and is frequently called upon to assist state health departments in that connection.

For those of you who are interested in this subject, or who some day may be decidedly so when engaged in projects in this country or others, where you must either solve your malaria problem or wreck your project or reputation, I desire to invite attention to the various Governmental reprints of the United States Public Health Service reports giving the information that engineers require and particularly to articles on impounded water in the Proceedings of Malaria Field Workers, published by the same Bureau. You can send for a printed list of such information and send later for any particular reprint, etc., you desire. Some of our American engineers working south of the Rio Grande where losses of labor efficiency and labor turnover amount to many thousands of dollars have failed to inform themselves relative to malaria control measures, and consequently have their working forces "riddled with malaria." Dr. L. O. Howard, the "father of mosquito control in the United States," estimated several years ago that malaria costs in our country amount to a hundred million dollars a year.

For those of you who desire to know in a few words how to prevent a body of impounded water from being a potential malaria menace the following information is submitted.

Malaria is conveyed from man to man by certain species of one family of mosquitoes and in no other way. This kind of mosquito is called the Anopheles. Nearly all of them have spotted or mottled wings, while others have clear wings. In our country the malaria mosquito responsible for nearly all of our malaria has four distinct dark spots on the wing and like the other malaria mosquito is said to "stand on its head." To distinguish a malaria mosquito from other kinds you observe its resting position. Most insects and mosquitoes rest with their bodies approximately parallel to the surface they are resting on. The malaria mosquito (Anopheles) does not. To the eye it looks like a brad, or small splinter, driven into the resting surface at an angle of 45° to the surface rested upon.

The malaria mosquito generally deposits its eggs in water where there is floating debris, aquatic vegetation, grasses, or other protection for its young. Two or three days after eggs are laid, small wiggle tails (mosquito larvae) come from the eggs and rest, live, and feed at the water surface. Larvae of most of the other mosquitoes are bottom feeders, hence the name wiggletails—they wiggle down, get food and float or wiggle back to the surface to get air.

We see then that both larvae and adults of the malaria conveying mosquito differ in resting position from other kinds of mosquitoes and are easy to distinguish. As the negro said, "De wiggletails of de malaria is high top floaters and de others go up and down."

Small fish (and particularly the surface feeding minnows) are nature's best enemy of the mosquito. The surface feeding Anopheles larvae are the preferential food of Gambusia, the small surface feeding minnow that gives direct birth to its young. This minnow thrives in nature, from Virginia and Central Illinois southwards.

As soon as you begin to impound water numerous small rafts of floatage, consisting of logs, small sticks, leaves, and other light debris, collect on the water surface. The Anopheles lays her eggs in this floating debris, and it is difficult for fish and other aquatic enemies to find them. Within an inch of the small wiggletail may be a dozen or ten dozen particles of debris that from below may look exactly like wiggletails. When the Anopheles larvae see their enemy approaching they generally remain perfectly quiet so that they may appear to be a small particle of floatage.

For these reasons *we consider floatage our main problem in mosquito control of impounded water projects.* We find that the wind has a way of driving it into inlets; and also that it collects at the upper ends of inlets to where it is washed down the streams from above. For those reasons most malaria mosquito larvae, when they occur in impounded waters, are to be found in the upper third or upper quarter of the inlets, bights, or indentations. Wave action where sufficiently constant and active drowns mosquito larvae. On one lake in central Alabama where a certain aquatic growth favors Anopheles production, a speed launch is used to eliminate mosquito larvae. Three launches have been worn out in this successful mosquito control work in the past ten mosquito seasons on this lake. The problem there was to eliminate malaria or close down a large coal mine.

High water and strong wave and wind action strand floatage along shore. This is one of nature's control methods. Let the engineer use it. Where we can, let us use flash boards and hold the water 2 feet, or 3 feet, if it is practical, above summer high water level. The winter winds take nearly all logs, sticks and floatage ashore for us. As soon as the mosquito season comes on we lower the water level a foot. All the flooded vegetation has been killed and the lowered water level gives us a clean shoreline where the fish and other aquatic enemies can get the last mosquito larva. The malaria mosquito generally does not lay her eggs along lakeshores in the absence of floatage or shoreline vegetation, as she knows they will be promptly gobbled up or killed.

If we have a constant level pond with vegetation in water at the edges, we often find the mosquito larvae at the water surface hiding in or protected by the vegetation. When we lower the water the larvae follow it and are exposed to fish, and any remaining behind are dried up and die. If before the malaria season is ended vegetation again protects mosquito larvae along the pond edge and larvae occur in it, then we can again lower the pond surface a foot—and thus remove the larvae to where the fish are waiting for them.

If we impound water during the mosquito season and thus cause much floatage to collect on the water surface at that time, conditions will probably be made decidedly favorable for maximum mosquito production.

If in addition the new lake is stocked with bass or other game fish which destroy the top feeding minnows and other kinds of fish and aquatic insects that prey on mosquito larvae, we should expect to increase the Anopheles supply. Instances of this nature have taken place with serious results.

In some recent engineering construction projects adequate precautions have been taken against the introduction of malaria carriers when new laborers were brought in.

Generally speaking, lakes with relatively clean shore lines, that are free of floatage do not produce Anopheles.

In some instances fish are able to prevent Anopheles production even in the presence of considerable aquatic vegetation. However with certain aquatic plants and particularly when algae (spirogyra) are present with vegetation and floatage it may happen that the fish, even when numerous, will be unable to prevent Anopheles production.

In one instance (a lake near Hartsville, S. C.) the lake surface was matted with pond lilies, water-shield, other aquatic plants and some spirogyra. The fish (Gambusia) were exceedingly numerous, and throughout an entire season Anopheles larvae were always devoured by Gambusia before reaching maturity. This was very exceptional.

To prevent production of Anopheles in lakes:

a. When practical hold the water about two feet or more higher in the non mosquito season than in summer. Use flashboards, gates or other regulating devices for water level control purposes. The object of lowering the water level is to strand floatage along the shoreline, to bring any mosquito larvae present away from vegetation protection and leave them at a clean shore edge where their enemies can get them. Also to make the shore line unattractive to mosquitoes.

b. Keep the water surface free of floatage.

c. When new aquatic plants appear, remove the first that come up. Cattails and some other plants multiply rapidly and are expensive to remove if given a good start.

d. In clearing brush, trees, etc., from the lake bed, make a good clean job of clearing in the upper third of all lake inlets. Wave protected inlets may become important breeding places of malaria conveying mosquitoes.

e. As mosquito production is generally at its maximum during the first three years after the water is impounded, weekly inspection of the lake may then be necessary.

f. In some instances collection and removal of floatage may be facilitated by using booms made of logs or saplings.

g. It is decidedly advisable to start fish hatcheries (for mosquito destroying fish) several years before water is impounded. It is not possible to overstock the lake with mosquito destroying fish.

h. To destroy mosquito larvae we apply oil or larvacides.

It should be mentioned that these malaria conveying mosquitoes are night feeders and do not become infected until more than a week after they have bitten a malaria carrier. Also that after taking a blood meal they nearly always rest on the bedroom walls for a day before leaving the building. By a systematic daily destruction of the engorged Anopheles in the bunk houses we can economically reduce the spread of malaria among our working forces.

Full details showing the value of this procedure are given in the August, 1920, number of "The Military Surgeon."

In order to prevent the spread of malaria near the lake above the Mitchell Dam on the Coosa River near Birmingham, Alabama, adequate precautionary measures were taken during the construction period, and as a result the malaria sick rate in the territory adjacent to the lake has been lower since the water was impounded than in previous years. Evidently, then, engineers can build malaria out of existence.

WATER SUPPLIES OF FLORIDA[1]

By E. L. Filby[2]

Florida and Florida water supplies have been bound together inseparably since Ponce de Leon in 1512, looking for the fabled "Fountain of Youth," discovered the land of flowers—Florida. In 1925, the year of the great migration to Florida, one could hear comments on Florida water in every hotel and tourist camp. Auto pilgrims from the north and west often brought water along or purchased bottled waters of brands familiar back home. Drink Florida water? No, sir! Even moving picture troupes taking scenes had bottled water for all members of the company, for the city water where they were living was not to be thus used—although it has been for years used by the railroads for drinking purposes. One heard marvelous tales. Florida's Fountain of Youth was discovered in many parts of the State. Her 30,000 odd lakes from Okeechobee, the largest fresh water lake entirely within the United States, thirty miles one way and forty the other, down to the smallest newly created subdivision lake together with hundreds of gushing, boiling springs, all became famous over night either for health giving qualities, fishing or beauty. With an average rainfall of 53 inches at Jacksonville, 59 inches at Jupiter, near West Palm Beach, 54 inches at Tampa and 56 at Pensacola, one can realize that Florida receives her share of J. Pluvius' product. A state average of 52 inches is a fair one. By virtue of water, Florida water, land values doubled and trebled. But enough—one of the state's big assets is her water supplies, her lakes, her springs and her coasts.

Water supply, geography and geology are all so inter-related that one must really and literally subdivide the state—not into business lots, but into certain districts familiar to all of you by name. Let us tour Florida on an inspection trip of her public water supplies, springs, etc. We will start as a traveler from Missouri—we enter Florida at her western portal—Pensacola. This city swears by its municipally-owned and operated water supply, proudly advertising on cards that Pensacola water is 100 per cent pure. The supply is from driven wells about 150 feet deep sunk into a water bearing sand geologically of the Pleistocene age. The supply is very soft having a hardness of only 12 parts per million and a total solids content of 41 parts per million. Chemically pretty near 100 per cent pure; they use it in automobile and boat batteries without distillation! No treatment is afforded the water. We will head east on the road to Jacksonville with possibly a few side trips.

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[1] Presented before the Buffalo Convention, June 9, 1926.

[2] Chief Engineer, State Board of Health, Jacksonville, Fla.

Bonifay a municipal supply, drilled 450 feet into what geologists term Vicksburgian limestone—the most reliable source of water in all Florida. Geologically all rocks in Florida are sedimentary and were for the most part deposited beneath the ocean, therefore, containing salt sea water. The principal source of springs and deep well supplies is the soft porous Vicksburgian limestone. Large underground channels must exist, but the rock ordinarily is honeycombed with small pores and passageways. The Vicksburg limestone is often subdivided into three formations, Ocala limestone, Peninsular limestone and Marianna limestone. Suffice to say practically all deep seated supplies of any importance or quantity are taken from the Vicksburg group of limestone. Bonifay water illustrates the fact that proceeding east we are getting into deeper wells and harder waters. Depth is now 450 feet and hardness 120 parts per million and total solids 140 parts per million.

At New Valparaiso the free flowing water with a temperature of 76°F. all year around is the basis of a new sanitarium. All this country west of Apalachicola River is rolling sandy clay hills to flat pine bottoms near the coast. It is purely agriculture and timber country.

A line from Apalachicola, the famous oyster center, east to St. Augustine, will include our next subdivision. Tallahassee, capital city, municipally owned plant, two wells 700 and 250 feet deep. Hardness of 130 parts per million. Water is probably from the Vicksburg limestone region. At Live Oak we have our first treated municipal supply. Chlorine is used to sterilize the water from a 660-foot well. The water is influenced by drainage wells nearby. The water at Live Oak has a hardness of 195 parts per million. Lake City, the first stop in Florida for hundreds of thousands of tourists from the midwest last fall, has a municipaly owned deep well supply, taking water from a 400-foot well. The water is hard, 200 parts per million. The presence of sulphur is in the form of H_2S. On to Jacksonville the metropolis of the State. The nearer the coast we get the deeper are the wells, the water harder and more sulphurous. Jacksonville, with a municipal supply of wells ranging from 750 to 1200 feet deep, free flowing wells and water highly laden with H_2S. The water is allowed to spill over into large covered reservoirs. The aeration removing a large portion of the dissolved gas. The water is also chlorinated. The Jacksonville city water has a temperature of about 82°F. It has a hardness of about 300 parts per million. Many small residential areas are served about Jacksonville by simply drilling a well and running mains from it, using natural pressure. On account of the hardness of the Jacksonville water and the decreasing flows from the wells, two studies have been made of surface supplies nearby, the Black Creek project and the St. Mary's River project. Both have as their objective a soft water supply. Color removal will be a problem in either. The matter involving from eleven to three million dollars has not been voted upon by the people.

St. Augustine after having used for years a free flow of sulphur water having a hardness of from 544 to 714 parts per million and a chloride content of 154 to 635 parts per million has developed where it "couldn't be done," a supply of shallow well water on the mainland. This water has a hardness of 250 parts per million and a chloride content of 50. It is aerated and chlorinated.

In all this area, 360 miles across and over 50 miles deep, not a single surface supply. With rolling sandy clay land and many streams adaptable for surface supplies not a one is used. Small towns, rural population, deep well supplies—nearly 100 per cent municipally owned and operated. In this area are two old time watering resorts. Hampton Springs in Taylor County and White Springs in Hamilton County. Both are cold sulphurous waters. White Springs boils up through a large circular hole in the rock and is located on the shore of the Swannee River and forms a stream of moderate size. Its flow is estimated at 32,400 gallons per minute. The flow probably comes from the Vicksburg limestones. At Panacea in Waukulla County a very large spring of soft water is used for medicinal purposes. At Green Cove Springs in Clay County, the Qui-si-sana springs merge from a circular orifice several feet deep in the bank of the St. Johns River—the water is usually 78°F. and sulphurous. At Suwannee in Suwannee County there is a sulphur spring discharging 52,000 gallons per minute of hard sulphur water, while near Falmouth a similar spring yields over 100,000 gallons per minute.

Now let us go down the Gold Coast, the East Coast of Florida to Miami!—the Magic City. Leaving St. Augustine we pass Hastings, potato center, having flowing wells for a supply, privately owned and operated. These wells are 250 feet deep, having a hardness of 800 parts per million and total solids of 1400 parts per million with 200 parts chlorides. Natural pressure is used by the Hastings Water Company. Ormond has just put into service a new supply from four 200-foot wells, all free flowing. The water is softened by addition of lime. Daytona Beach now includes the three cities of Daytona, Daytona Beach and Seabreeze. Daytona has 8 wells from 162 to 250 feet deep. The water is aerated to remove sulphur and treated with lime to reduce hardness. The treatment is simply to aerate, add lime, allow to settle, decant and pump to town. The entire new system and plant to serve the greater city is now being designed by Metcalf and Eddy of Boston. New Smyrna is just completing a new pipe line for the city wells 3 miles west and has just drilled two more. The present supply is from two 180-foot wells with a hardness of 840 parts per million, a chloride content of 1500 and a total solids of 2940 parts per million. Going south Titusville is the next stop. Here four 20-foot wells are used. They are located to the west of the city to avoid salt water infiltration. Even here a hardness of 230 parts per million is reported. Cocoa, after using both deep and shallow wells, is now, on account of hardness and salt water, contemplating going 5 miles west to the headwaters of the St. Johns River for a surface supply.

Ft. Pierce uses 800-foot wells yielding free flow. The water is quite hard, 332 parts per million, and sulphurous. It is slightly aerated. A new three million gallon rapid sand filtration, iron removal plant is being built to use a savanna water some 2 miles south of the city. Color and iron will be problems as well as quantity of water. All the foregoing plants have been municipally owned and operated, and tendency toward shallow wells to avoid excessive hardness, salinity and sulphur is noted. The future drift is toward softer waters.

Stuart is our first privately owned and operated water system of any magnitude on the east coast. Here 60-foot wells are used and no treatment provided. West Palm Beach is served by the West

Palm Beach Water Company, a Florida East Coast Company property. Water is taken from a series of lakes or savannas, just west of the city and the sand dunes that run along the entire coast. This highly colored water is treated with alum, aerated, settled, filtered and chlorinated. The color is reduced from 102 to 23 parts per million. Mr. Y. C. Mar, chemist in charge, states that although they deliver a water to the mains having a pH of 6.8 no red water troubles result. Shallow wells, about 90 feet deep, are also pumped to help on peak loads. The present plant of six million gallons capacity is being enlarged to twenty million gallons under the direction of Mr. Pirnie of Hazen and Whipple of New York. With this added capacity, the wells will probably be abandoned. An interesting feature of this plant is that the filters and galleries are not housed at all. The clear well is covered.

From West Palm Beach one travels through the "Promised Land." Subdivisions are on each side. Boca Raton is an incorporated city of some 64 square miles including three large subdivisions, Croissantania, Mitzner's, Boca Ratone and Del Ratone, in addition to the former town of Boca Ratone. Population now is about 500. Water is taken from four 40-foot wells and the Kewannee pressure tank system is used. As each subdivision grows it is proposed to locate a small water system in each and formally connect them. There are 50 taps to this supply.

Ft. Lauderdale, the next city, has just spent $120,000 on a new 1,600,000 gallon plant. Two 16-inch shallow wells supply the city. Old wells, although only 80-foot deep, are to be abandoned because of salt water infiltration. Hollywood, Mr. Young's development, has been incorporated and now includes the old village of Dania which had a municipally owned supply from shallow wells, about 70 feet deep. The old wells yielded a water of about 322 parts per million hardness. Hollywood uses an old Kewannee horizontal pressure tank system at one plant and direct suction on six 65-foot wells at another plant pumping direct to the mains. A complete central water softening plant is hoped for in the near future.

The Magic City is next, Miami, the Mecca of Florida-bound tourists. Miami is supplied largely from shallow wells in what is known as the Hialeah section some 7 miles west of the city. The water is hard, having about 250 parts per million permanent hardness, with a color of about 60 parts per million. The plant is a lime softening filtration plant. It was designed for 10 million gallons per day in

1924 and completed in May 1925. Four months later in September it was decided to double the capacity and this has just been done. Even now, however, certain sections of the city are served by untreated shallow well water from scattered stations. The city of Miami owns and operates the Hialeah softening plant, selling the output to the Miami Water Company who retail it about Miami and also sell the municipality of Miami Beach, who in turn retail it. The softening plant is of the most modern design, being designed by Alvord, Burdick and Howson of Chicago, with Chas. P. Hoover as consultant chemist. Dorr clarifiers and equipment are used. The water is carbonated and then filtered. Spanish architecture is well utilized in creating a very pleasant looking filtration plant. It is hoped that the drainage in the Everglades will not cause the salt water to come that far inland and spoil the wells.

Coral Gables adjoins Miami and here the supply is from shallow wells about 80 feet deep, each well has its own pump and chlorinator. It is privately owned and operated, having just been sold by the developers to the Florida Power and Light Company. Homestead is our last stop on the Florida East Coast Mainland. Here is a municipality owning and operating a softening plant. The well is 72-foot deep and the water is aerated, treated occasionally with lime and soda ash, settled and filtered. Water with about 190 parts per million hardness is treated. Owing to the fact that the operator judges results by the clearness of the water, the softening process has been discontinued. The plant has been in service about a year and the water chemically treated about five times. Homestead is the site of one of the Florida East Coast Railway line softening plants and the water here is loaded into tank cars and hauled to the terminus at Key West. None of the keys have fresh water available except cistern rain water. Wells have always encountered salt water. So the water is hauled a distance of 122 miles in iron tank cars. The demand for a water supply at Key West was such that last year Governor Martin called a special session of the state legislature last fall to pass a bill authorizing the creation of the Key West Water District. The Commissioners of the District have now practically settled on a plan to bring water from near Homestead in a 122-mile pipe line along the Florida East Coast railway right-of-way and trestles or along the new overseas highway now being constructed to connect Key West to the Mainland. No pure water in Key West has been the check-rein on the city's growth. It is understood a private company is to put down the pipe line under guaranteed yearly sales to the city, Florida East Coast Railway, etc. In all this strip of land nearly 500 miles from St. Augustine to Key West, possibly averaging 5 miles in width, we have sand dune, waste land and sand country to coral rock formation, with the arms of the Atlantic on one side and the St. Johns and Everglades on the other. Not a spring of any size is found and the deep well waters in the Vicksburg strata are hard and often very saline. Most supplies are shallow wells set far back from the river front. It is very possible that these in time will become salt and the eyes of the future rest upon Lake Okeechobee and the Everglades drainage canals as the future water supply of the southern east coast.

Now we will go by boat to the winter home of Ford and Edison, Ft. Myers. Here is a municipal supply from deep wells sunk into the Vicksburg formation, a hard sulphurous supply, 650 parts per million, with over 700 parts per million chloride, has led the city to plan the use of the headwaters of the Caloosahatchee River. The lower west coast cities are situated on salt water which extends far inland since the country is very flat. Punta Gorda on Charlotte Harbor has just brought in a relatively soft water supply from a group of 95-foot wells. The supply is municipally owned and operated. Sarasota, the Wonder City, has a municipal supply, deep wells, about 400 feet deep sunk into the Vicksburg formation yielding a hard 556 parts per million water. Bradenton uses shallow wells only 85 feet deep and has been long experimenting to find an increased supply of soft water. The present supply has a hardness of nearly 1100 parts per million, a chlorides content of 240 parts per million and quite sulphurous. The yield is barely sufficient to supply the city. Here is an ideal location for a District Water Supply, taken from the headwaters of the Manatee River, with a color removal and softening plant to serve Bradenton, Palmetto, Manatee, Ellenton and possibly Sarasota.

Tampa, the west coast metropolis, has just put into service a new water softening color removal, filter plant, in the Hillsborough River in the northern section of the city. This plant, designed by Nicholas S. Hill, Jr. of New York, contains many splendid features and worthy of a special paper before this body. Suffice to say everything possible is metered, everything possible to secure flexibility of operation has been installed and the latest features in filtration design have been incorporated. The raw water varies from a fairly soft colored water, due to swamps and vegetation on the water shed during high river stage, to hard water of low color during low water stage in the river, due to the numerous springs discharging from the limerock into the river. In addition to lime and alum treatment the plant is using sulphur dioxide as a bleaching agent for removal of color. This is done by burning sulphur, passing the sulphur dioxide over a water scrubber and adding the H_2SO_3 thus formed to the water. Carbonization and chlorination are also used. The city owns the plant and has provided a complete chemical and bacteriological laboratory and trained operating personnel. The plant has a capacity of fifteen million gallons per day. The deep wells which long supplied Tampa will be held in reserve. Continued heavy draft during the fall of 1925 had rendered the salt content very noticeable. These wells are also in the Vicksburg strata about 200 feet deep. The presence of drainage wells used to dry surface ponds and depressions tends to pollute the underground water. Operating inside the city limits are two good sized water companies, the Seminole Heights Water Company and the Purity Springs Water Company. Just below the city water filtration plant is the famous Sulphur Springs. This flow comes from a large hole in what is termed the Tampa formation limestones and flows about 65,000 gallons per minute. It is used as a swimming pool.

Crossing the longest highway bridge in the World, Gandy Bridge, across Old Tampa Bay we are in the Sunshine City, St. Petersburg. The municipal supply here is from 200-foot wells drilled about the shores of two small lakes within the city limits. The water is aerated and chlorinated. It will average about 400 parts per million hardness. The wells are of the Layne Bowler type. The city has now engaged Mr. Hill to report on a new water supply. Other cities on the Pinellas peninsular such as Safety Harbor, Clearwater, Dunedin, Passagrille, etc., have deep well supplies with no treatment. Most of the supplies are muncipally owned and operated. At Safety Harbor is a well known spring having medicinal qualities, Espiritu Santo Spring—a spring having about 1800 parts per million chlorides and 900 hardness, 110 parts per million magnesium and 1000 parts per million sodium and potassium. The yields vary slightly, but the salt and sulphur water is used for bottling and medicinal purposes. Tarpon Springs, the world's largest sponge market, is now building a filter plant to use Lake Butler Water.

We will now go inland coming north from Okeechobee Lake.

Okeechobee City has just completed a new filtration plant of the rapid sand type and will be the first real test plant on Lake Okeechobee water. Lime and alum and chlorine will be used. Color removal will be a problem and at times vegetable growths. Moore Haven and Clewiston also have small filter plants using lake or canal water. Coming northwest we enter the famous ridge country, the land of lakes by the thousand and orange groves by the mile. Small towns are frequent, all using deep well supplies. The waters usually have a hardness of between 100 and 200 parts per million. Sulphur is not a problem. Bacterially the water is excellent. Although a town may have as high as 100 lakes within the city limits, water is taken from deep wells. A little to the west in the Peace River Valley, free flows are obtained, but the water is hard and sulphurous. Most all of the supplies are municipally owned and operated. About Orlando we have all deep wells, drilled into the Vicksburg strata and producing hard water. We have also many drainage wells sunk for farm drainage and storm water drainage, but fortunately no contamination of a public water supply has been ever recorded due to drainage wells in this vicinity. Orlando takes her water from Lake Ivanhoe, using rapid sand filters and chlorine for purification. This plant has been described in THE JOURNAL (March, 1926). It is the only filter plant in this section and is under chemical and bacteriological control. A small group of privately owned deep well plants are centered about Eustis. Mount Dora is putting in a new lake supply with chlorine to augment a deep well hard water.

Ocala, in the Kingdom of the Sun, uses deep well water, chlorinated. Six miles east is the famous Silver Springs, the largest spring in the world, creating a navigable river at its source. The water issues from several openings and the flow is about 385,000 gallons per minute. The water is crystal clear, objects in 80 feet of water being clearly visible at the bottom, fish, turtles and aquatic life can be observed clearly through glass bottomed boats touring the springs. This spring issues from the porous and cavernous Vicksburg limestones and as it does not travel very far through it, the water is not very hard. Another spring nearby is Blue Springs near Juliette with a flow of about 350,000 gallons per minute. Gainesville, University City, uses deep wells, 380 feet into the Vicksburg strata and also a spring supply which is chlorinated. The land about Gainesville and Ocala is rolling country full of limestone sinks. Small ponds and depressions abound. One large sink near Gainesville called Paynes Prairie, was at one time the outlet of a large stream. The outlet became closed by logs and rubbish and a great lake was formed. The sink

TABLE 1

Florida public water supplies

MUNICIPALLY OWNED AND OPERATED		PRIVATELY OWNED AND OPERATED
Surface supplies—untreated		*Surface supplies*—untreated
		Bellview
Surface supplies—chlorinated		
Mount Dora (Part)		
Surface supplies—filtered and chlorinated		*Surface supplies*—filtered and chlorinated
Tarpon Springs		Clewiston
Moore Haven		West Palm Beach (Part)
Okeechobee		
Orlando		
Tampa (Part)		
Shallow wells—no treatment		*Shallow wells*—no treatment
Titusville	Delray	Stuart
Cocoa	Boca Raton	Elfers
Melbourne	Dania	Perry
Lake Worth	Hollywood	Miami (Part)
Boynton	Bradenton	
Shallow wells—softened		*Shallow wells*—softened
Fort Lauderdale		Sunny Isles
Homestead		
Shallow wells—chlorinated		*Shallow wells*—chlorinated
St. Augustine (Part)		Coral Gables
		West Palm Beach (Part)
Springs		
Tampa (Part)—chlorinated		
Palatka (Part)—chlorinated		
Gainesville (Part)		
PRIVATE SOURCE—MUNICIPAL DISTRIBUTION		MUNICIPAL SOURCE—PRIVATE DISTRIBUTION
Deep wells—no treatment		
Dunedin		
Haines City		
Winter Park		
Shallow wells—no treatment		*Shallow wells*—no treatment
Delray Beach		
Shallow wells—softened		*Shallow wells*—softened
Miami Beach		Miami (Part)

TABLE 2

Florida public water supplies

MUNICIPALLY OWNED AND OPERATED	PRIVATELY OWNED AND OPERATED
Deep wells—no treatment	*Deep wells*—no treatment
Bunnell New Smyrna DeLand Lake Helen Punta Gorda Plant City Largo Clearwater Zephyrhills Dade City Passa-Grille Brooksville Inverness Crystal River Dunnellon Bowling Green Sebring New Port Richey Mulberry Lakeland Fort Meade Bartow Auburndale Lake Alfred Davenport St. Cloud Bushnell Center Hill Webster Umatilla Leesburg Groveland Clermont Winter Garden Ocoee Longwood Williston Newberry Alachua Archer Starke Lake City Pensacola Milton Bonifay Chipley Green Cove Springs DeFuniak Springs Marianna Panama City Apalachicola Blountstown Quincy Havana Tallahassee Monticello Greenville Madison Jasper Jennings Mayo Eagle Lake Sarasota Daytona (Part) Tampa (Part) Mount Dora (Part) Gainesville (Part) Palatka (Part)	Orange City Safety Harbor Avon Park Brewster Pierce Winter Haven Lake Wales Tavares Eustis Fruitland Park Apopka Wiersdale Bagdad River Junction Alton Tampa (Part) Bellair
Deep wells—softened	
Ormond Daytona (Part)	

TABLE 2—*Continued*

MUNICIPALLY OWNED AND OPERATED		PRIVATELY OWNED AND OPERATED
Deep wells—chlorinated		
St. Petersburg		
Sanford		
Ocala		
High Springs		
Live Oak		
Flowing wells—Artesian, no treatment		*Flowing wells*—Artesian, no treatment
Fernandina	Arcadia	Hastings
Jacksonville Beach	Wauchula	Century
Callahan	Frostproof	Everglades
Port Pierce	Kissimmee	
Fort Myers	Crescent City	
Palmetto		
Manatee	Graceville	
Flowing wells—chlorinated		
Jacksonville		
South Jacksonville		
Flowing wells—softened		
Vero Beach		

later reopened and the basin drained effectively putting an end to the steamboat traffic on the lake. Only a few caverns are known and they are not developed here as in the Shenandoah Valley in Virginia.

Palatka, on the St. Johns River, has a municipally owned and operated supply of free flowing wells, 250 feet deep and a spring. Palatka is interesting in that the supply from the springs is piped separately about town from the well supply, thus there are two systems, a soft and a hard water system.

Some interesting facts about the Florida water supplies can be gathered by a study of the United States Geological Survey chemical analyses of our waters and a study of Water Supply Paper No. 319 of that Service, although many new supplies have been developed since then. At present we have 160 water supplies in Florida serving the general public. We have not listed the small supply from free flowing wells piped to 20 or 30 houses unless it is the only supply in the vicinity. Thus in Jacksonville we omit supplies of Brentwood, Ortega, St. Johns Park, Panama Park, etc. in the suburbs about the city. Large subdivisions are noted only when the supply is in actual use. To keep up with the water supplies of subdivisions is well nigh impossible and we always urge prospective buyers to investigate before you invest, see where your supply is coming from. It is interesting to note that from August 1, 1925, to January 1, 1926, in spite of an embargo on many commodities, three cast iron pipe manufacturing companies

TABLE 3

Florida public water supplies

MUNICIPALLY OWNED AND OPERATED				PRIVATELY OWNED AND OPERATED			
A. Deep wells	91			A. Deep wells	19		
1. Static		74		1. Static		16	
a. no treatment			67	a. no treatment			16
b. chlorinated			5	b. chlorinated			0
c. softened			2				
2. Flowing		17		2. Flowing		3	
a. no treatment			15	a. no treatment			3
b. chlorinated			2	b. chlorinated			0
B. Shallow wells		13		B. Shallow wells		7	
1. no treatment		10		1. no treatment			4
2. chlorinated			1	2. chlorinated			2
3. softened			2	3. softened			1
C. Surface supplies		6		C. Surface supplies		3	
1. no treatment			0	1. filtered & cl.			2
2. filtered & cl.			5	2. chlorinated only			0
3. chlorinated only			1	3. no treatment			1
D. Springs		3		D. Springs		0	
1. no treatment			0				
2. chlorinated			3				
			113				29
			5				3
			108				26

5. Private source, municipal distribution
1. Municipal source, private distribution
14. Subdivision supplies
7. Institutional supplies

Grand total 160 supplies

126. Deep well supplies
26. Shallow well supplies
4. Spring supplies
10. Surface supplies (7 filtered and chlorinated)
8. Filtered supplies
19. Chlorinated supplies
7. Softening plants

reported the sale of over 660 miles of pipe for water supply purposes from 2-inch up.

From tables 1, 2 and 3 you will note we have 109 municipally owned and operated water plants in Florida and 26 privately owned and operated. We have 5 supplies with private source and municipal distribution systems and one large supply with municipal owned source and private distribution systems. Of the 141 cities thus listed deep wells are used exclusively in 107 cases, and 6 partly served. Shallow wells are used in 20 places, or 2 in part. Surface supplies are used in 6 cases and 3 in part.

The State Board of Health maintains a laboratory at Jacksonville attached to the Engineering Division for the purpose of bacterial examination of the waters. No charge is rendered, but cities are required to own their own shipping cases which we order for the special price of $14.50. Tests are made as frequently as the cities desire. Where cities do not own their own sample case, our field inspectors, 11 in number, and two field engineers collect samples in State Board of Health boxes. Samples are shipped iced and usually received at Jacksonville within 24 hours by special handling procedure with the express companies. It is expected to have chemical control over the plants starting next year. The United States Geological Survey has just this year finished chemical tests on over 500 waters in Florida.

In conclusion, let me give you the sage advice as published in our leading newspaper under a dispatch line from Sebring, Florida:

> Before locating in Florida or any other state in the Union, the first thing that should be considered is the water as all physicians and surgeons will tell you that your health and the health of your family depends upon the quality of water which you drink. No matter how beautiful your home or surroundings or how delightful the weather or how much money you can make, if the water is not of the best, all the other things count for nothing. Good health and no one will deny it is the most consideration to man on earth.
>
> Sebring's water is rightly called water from the fountain of youth. It is not only medicinally good for all ailments, but it clears the complexion, makes our women more beautiful, our men more manly—vanity cases,' setting up exercises are not needed in Sebring. The water even makes you immune from typhoid fever. It seems but wilful waste for the inhabitants of Sebring to bathe and wash their clothes, sprinkle their lawns and freshen their flowers, with water that is equal if not superior to the highly retailed health water.

THE PROBABLE FUTURE DEVELOPMENT OF RAILWAY WATER TREATMENT[1]

By C. R. Knowles[2]

The railroads have passed through the period of pioneer development in the treatment of locomotive water supplies and are now approaching an era of refinement that will undoubtedly lead to still greater development. The foundation of water softening and treating practice has been laid, and it is unlikely that there will be any radical departure from these principles. At the same time it is becoming more and more apparent that refinement must take place in many of the present methods of treatment and that careful consideration should be given to the possibilities of new methods.

As far as the railroads are concerned, water treatment has not only been an economic necessity, but in many cases it has been an actual operating necessity. As train loads became heavier and boiler pressures and ratings were increased the treatment of many of the worst waters became imperative. The available information regarding methods of treatment was limited, and many of those who first undertook to treat the water were confronted with the problem for the first time and were probably in the same state of mind as the first man who started out to soften water more than eighty years ago, the idea in the beginning being simply to get the water in a tank, add the necessary chemicals and let it settle. Certain refinements were developed through experience as time went on and it may be expected that the art will continue to develop by the same process.

It was quite natural that the worst waters should receive attention first, for while the less troublesome waters of comparatively low scaling content were costly from the standpoint of fuel economy and boiler maintenance, they did not interfere seriously with train operation. As treatment has been extended to include practically all of these very bad waters, the water that was considered fair a few years ago has become the bad water of today. The value of water treatment has become so well established through records of savings in boiler repairs, fuel economies and the reduction of engine failures that it is becoming apparent that treatment must be extended to include these waters of so-called fair quality. The cost of providing adequate motive power for the movement of trains is constantly increasing, and with investments of from $60,000 to $70,000 each for locomotives, poor water conditions can no longer be tolerated.

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[1] Presented before the sessions of Committee No. 19, Boiler Feed Water Studies, Buffalo Convention, June 9, 1926.

[2] Superintendent Water Service, Illinois Central System, Chicago, Ill.

Longer engine runs are another factor in locomotive operation that is making better water conditions necessary. The Northern Pacific recently made a record breaking continuous freight run in which a Mikado type coal-burning locomotive pulled a train from Seattle, Wash., to St. Paul, Minn., without being uncoupled from the train and without receiving any terminal attention enroute. The distance of 1,898 miles over three mountain ranges with maximum grades of 2.2 per cent was covered in 109½ hours total time. The Great Northern a short time ago ran an engine and train from Seattle to St. Paul and return, a total distance of 3462 miles, while the Burlington handled a train of 90 cars loaded with 6450 tons of coal from West Frankfort to Chicago, a distance of 413 miles with one mountain type locomotive. The Southern Pacific is running passenger trains regularly betweed El Paso and Houston, Texas, a distance of 832 miles, without changing engines. While many of these long runs are test runs today, they will be a regular thing in the near future.

All of these developments in locomotive operation call for water supplies of the highest quality, and it is evident that the railroads are going to demand much more of the water service engineer in the future than they have in the past. Some of the improvements in the quality of water will no doubt be accomplished through the development of new and better supplies, but in the great majority of cases it will mean the improvement of existing facilities by establishing additional treating plants, etc.

REMOVAL OF SUSPENDED MATTER

One of the problems that will undoubtedly receive more attention in the future than it has in the past is the removal of mud or other suspended matter from railroad water supplies. While mud removal has not been altogether neglected, it has hardly received the attention it deserves, to say the least. This apparent neglect is not due entirely to failure to appreciate the importance of removing suspended matter, but rather to the fact that through necessity efforts were concentrated on improving waters high in dissolved solids, and in some instances to lack of sufficient finances to provide the required facilities.

The rivers of the Middle West carry an average of from 1 to 1½ pounds of suspended matter per thousand gallons of water throughout the year with a maximum of 5 or 6 pounds during the freshet seasons, while the Southern and some of the Western streams carry still more. The objection to the presence of mud or other suspended matter in boiler waters is not altogether due to the necessity for frequent washing of boilers to prevent foaming and possible mud burning of sheets due to the use of turbid water, but also to the fact that the mud is deposited on the tubes and sheets and in the presence of dissolved solids helps to form scale.

Mud removal installations consist largely of sedimentation basins alone. They are fairly effective where the mud is heavy and settles rapidly, but the most satisfactory results can be secured by coagulation and sedimentation, followed by filtration. Most turbid waters carry considerable amounts of scale forming solids in addition to the suspended matter and as softening the water as well as removing the mud add little to the cost, the development along this line will probably include complete softening equipment for the removal of matter in solution as well as in suspension.

FILTERS

Another possible future development of water treatment is the more extensive use of filters. A large majority of the railway water treating plants depend entirely upon sedimentation to produce a clear treated water, although the limitation of sedimentation alone in clarifying the water is recognized in the extensive use of iron and alum in various forms as an aid to the precipitation of the sludge.

It is a commonly accepted fact that the temporary hardness remaining in water after being softened with lime and soda ash is materially lowered by filtration through sand. Where filters are used in conjunction with lime and soda ash softeners no other coagulant is required, as a general rule. The amount of suspended solids that may be removed by filtration, even after treatment and sedimentation, is of appreciable value, not only in reducing the hardness and preventing after-precipitation in distribution systems, but also in reducing the losses in fuel and water through less frequent blowdowns of boilers. Filtration may well be compared to a continuous blowdown in its effect, as the suspended matter that would otherwise remain in the water after ordinary treatment is being removed constantly as the water is passing through the filter.

The additional cost of filters has been fully justified by the roads that are using them and their universal adoption as an adjunct to water softening will undoubtedly follow as their value becomes better recognized.

TREATING TANKS

Improvement in design of water treating plants will no doubt include a more efficient type of treating tank, particularly in regard to sludge removal. Many different designs have been followed in the construction of reaction and sedimentation tanks, the most widely used being the common flat bottom tank, either of the standpipe type with the bottom at the ground level, or erected on an elevated tower. In this type of tank, as commonly used, the sludge is deposited over the entire bottom of the tank, its removal necessitating the construction of an expensive sludge-collecting system, which at its best leaves much to be desired. This sludge removal system usually consists of an arrangement of pipes with openings placed at uniform intervals over the bottom of the tank. In the large tanks they are so arranged that they may be operated in sections with from two to four sludge valves for each tank. Another type is so arranged that the collecting pipes may be rotated over the bottom of the tank. None of these systems are entirely satisfactory for they do not completely remove the sludge and they are extremely wasteful of water, as the sludge nearest the outlet is the first to be picked up and two-thirds of the openings are usually discharging clear water before the sludge at the outer edge of the tank is disturbed.

One of the principal developments in the design of treating tanks is the conical bottom tank with a large riser pipe. The angle or slope of the cone is 45 degrees, and the drum or riser pipe is from 4 to 6 feet in diameter and serves as a sludge-collecting chamber. The sludge falls to the bottom and is collected in the mud drum as it forms, where it is easily and completely removed through a single opening and with a minimum waste of water. Actual tests to determine the amount of water used in removing sludge show that the flat bottom tank requires from five to ten times more water in sludging than a conical bottom tank of proper design.

The remarkable efficiency of the conical bottom tank in sludge removal and economy in the use of wash water are factors that will result in its more extensive use for water treatment. Experiments are also being conducted with continuous sludge removal systems and tanks of other designs, and it is evident that the development of water softening will include tanks of more efficient design.

ZEOLITE SOFTENERS

Zeolite water softeners are receiving considerable attention as a possible method of treating water for locomotives. One installation on a Western road is being watched with much interest and the results obtained will undoubtedly be a factor in determining their use by other roads, as well as extending their use on the road in question.

The chief concern regarding the use of Zeolite is on account of the possibility of increased foaming due to the conversion of the various elements in the untreated water to sodium compounds in the treated water, which is characteristic of Zeolite treatment. It is claimed that the foaming may be minimized with the exclusive use of Zeolite treated water, which is practically free from suspended matter. This is not always possible on a railroad unless entire engine districts are equipped with Zeolite treatment. Another factor which has reacted against their use for railroad supplies is the fact that with certain waters pre-treatment is necessary. For example, if the water contains an appreciable quantity of iron it must be pre-treated before passing through the Zeolite softener, or if the water is turbid it must be filtered before it can be handled successfully. With the lime and soda ash plant no pre-filtration are required, as sand filtration after reaction and sedimentation is provided in all modern equipment.

A possible solution of the problem is a combination lime-soda-Zeolite plant with pre-treatment by lime and soda ash for the removal of the bicarbonates of lime and magnesia, iron and free carbon dioxide, the neutralization of sulphates and the reduction of organic matter, silica and alumina, followed by the Zeolite treatment to produce a water of zero hardness with a minimum of suspended matter. If this type of plant can be developed successfully and economically it is not at all unlikely that Zeolite treatment will be further extended in the treatment of locomotive supplies.

INTERNAL TREATMENT

Internal treatment of boiler waters involves the introduction of chemicals and other substances into storage tanks, the tenders of locomotives or direct into the boiler. This method of treatment as applied direct to boilers is the oldest form of treatment known, probably being as old as boilers themselves. It has been improved upon from the old hit-and-miss form of treatment until it has become a generally accepted process. Reputable manufacturers offer forms of treatment that are based upon chemical examination of the water and that are producing good results. The combination of chemicals used in this form of treatment is generally referred to as boiler compound. The future development of this form of treatment will be the elimination of the quack cure-all compounds and more uniform methods of feeding the chemicals to the water, probably through a more extensive use of compound feeders.

GENERAL

Stationary power plants are adapted to the use of many devices for the purification of boiler feed waters that cannot be used on locomotives on account of the limited space available. Therefore, it is impossible to make any prediction as to the probable future use of de-aerators, de-concentrators, etc., on locomotives, although their development for this purpose is not beyond the realm of possibility. In fact many of the feed-water heaters used on locomotives embody the feature of oxygen removal in addition to heating the feed water. Some authorities claim great benefits from this feature in preventing corrosion, and it is possible that as more locomotives are equipped with the open type of feed water heater they will become an important factor in improving the quality of the feed water. The claim is also made that thermic syphons and plates as installed in locomotive boilers tend to improve feed water conditions, particularly as regards corrosion, through increased circulation of the water in the boiler.

It is impossible to make any prediction as to the possible future development in the use of the less common reagents in water softening, such as the barium salts for example. As with many other reagents, treatment with barium is not yet commercially practicable as a rule, although barium salts may ultimately be manufactured at a cost that will result in their more general use. However, the principal developments, in the near future at any rate, will be based upon the lime-soda ash treatment.

There is ample room for further development in railway water treatment; at the same time there are certain limitations that must be considered. Water softening and treatment for steam making must of necessity be kept within the bounds of the more simple reaction and commercial reagents.

STREAM POLLUTION AND ITS EFFECTS[1]

By N. T. Veatch, Jr.[2]

We are all fairly familiar with the results of stream pollution as evidenced by the black, ill smelling water of some familiar stream, but there seems to be a general lack of understanding on the part of the public at large, in regard to the importance of this question and its relation to public welfare. The popular conception of "stream pollution" seems to be synonymous with "nuisance" as regards offense to smell and sight, whereas this feature is but one of the phases of the subject and by no means the most important.

The protection of our streams, and other bodies of water as well, is nothing more nor less than the protection of a national resource, in fact, one of our most valuable national resources, since it concerns the all important question of public water supply and, therefore, all city dwellers in locations where ground water supplies are not available. Some industries, as fisheries, are entirely dependent on reasonably pure stream water and all industries are dependent on water supplies of some nature.

By no means the least important feature of this question is the fact that it is becoming more and more acute each year through the increase in urban population, the increase in the number of municipal sewer systems, the increase in industries which produce objectionable trade wastes and in the rapidly increasing number of cities which are being forced to use surface water to get an adequate supply.

The increase in the urban population of the United States is shown in the following table adapted from the United States Census which shows that the urban population of the United States in 1920 exceeded the rural by approximately 3 million, and there is every indication that this excess will continue to increase.

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[1] Presented before the Iowa Section meeting, November 4, 1926.

[2] Consulting Engineer, Kansas, City Mo.

	1900	1910	1920
Population of United States.......	76,000,000	92,000,000	106,000,000
Rural............................	46,000,000	50,000,000	51,500,000
Urban..	30,000,000	42,000,000	54,500,000

There seem to be no available authentic data on the number of sewer systems in the United States, but, based on experience in the central west, it may be stated that at the present time a town of 2000 without a municipal sewer system is decidedly exceptional, and that probably 75 per cent of these systems have been built in the past 20 years. It is, therefore, reasonable to assume that within 20 years, practically all towns of 1000 and over will be served with sewers. Similarly, there seem to be no available authentic data in regard to the change of municipal ground water supplies over the country to surface water, but again judging from experience in the central west where numerous cities have had to make this change, through inadequacy of ground water supplies, this factor is important.

The Manual of the American Waterworks Association estimates the number of water works in the United States as 9850 in 1924, of which 36 per cent are surface supplies. In view of the fact that practically all of the cities in excess of 30,000 are included in the 36 per cent, it is probably safe to say that 75 per cent of the urban population of the United States, is served with surface water from streams, lakes or artificial reservoirs, and that approximately half of this number or 20 million persons, are served from water supplies taken from streams which are subject to pollution from municipal sewage, trade waste, or drainage from barn yards or feed lots. When it is considered that the above condition exists at such important centers as Philadelphia, Pittsburgh, Baltimore, St. Louis, Cincinnati, Louisville, New Orleans, Kansas City, Omaha, Oklahoma City and many others, the importance of this question may be seen.

The present standard of purity as set forth by the International Joint Commission in 1913, in an extensive investigation of boundary waters, considered as safe for surface waters which are to be purified by modern plants, consisting of settling and coagulating basins, filters and sterilizing equipment, demands that "the raw water shall not have objectionable odor, color, or taste, and shall not contain more than 500 bacteria of the intestinal type (B. coli) per cubic centimeter." Practice has shown that the above is not a bad standard, although satisfactory water is produced at many places where this standard is often exceeded, but the fact remains that the use of such water is dangerous and puts too heavy a load on the purification plant. This extra burden surely should fall on those agencies causing the pollution, which calls for purification of sewage and trade wastes where pollutions exceed a safe limit. As a matter of fact some of the streams of the country are called upon to furnish water for municipal water supplies at a rate which in the aggregate exceeds the flow of the stream at times. This was true of the Verdegris River in Kansas in the fall of 1917, when the aggregate amount of water used by Kansas municipalities, along its course, was approximately three times its flow at the Oklahoma State line.

The chief source of stream pollution is undoubtedly municipal sanitary sewage which may be made up of anything, but which is reasonably uniform except as to trade wastes.

For the study of stream pollution the character of sewage is customarily reported as solids both in suspension and in solution, as organic matter in the form of total nitrogen and "oxygen consumed" and as "biochemical" or "biological oxygen demand" which last is a measure of the oxygen required to mineralize the organic matter in the sewage.

Bulletin 143 of the United States Public Health Service states that average domestic combined sewage without major trade waste will contain the following constituents in grams per capita per day.

Total Solids	439
Dissolved Solids	330
Suspended Solids	109
Total nitrogen	11.4
Oxygen consumed	51.5
Biological oxygen demand	100

For a city of 10,000 persons, therefore 1,000,000 grams or 2204 pounds of oxygen will be required for sanitary sewage.

Trade wastes are of course more variable and require special study in each instance. They may range from sawdust which has practically no effect on the water, to wastes from coal tar product works which cause objectionable tastes in waters in several million dilutions of pure water.

Several specific wastes have been studied and found to contain total nitrogen and oxygen consumed as shown in table 1, which also gives the approximate equivalent of the waste in terms of sanitary sewage.

TABLE 1

*Estimated average amounts of total nitrogen and oxygen consumed contained in various industrial wastes, per unit of product, raw material or labor, with approximate equivalents in domestic sewage**

NATURE OF WASTE	UNIT OF MEASUREMENT	GRAMS PER UNIT		APPROXIMATE NUMBER OF PERSONS REQUIRED TO PRODUCE THE EQUIVALENT OF THIS WASTE IN DOMESTIC SEWAGE
		Total Nitrogen	Oxygen Consumed	
Slaughter house	1 animal	238.6	183.7	7
Pork packing	1 animal	243.1	307.5	9
General packing	1 animal	171.5	344.2	8
Glue making	1 employee	3,193.3	4,427.1	102
Soap making	1 employee	27.2	2,084.7	33
Wool scouring	100 lb. raw material	340.2	1,551.3	30
Wool cloth dye and scour	100 lb. raw material	704.4	7,112.4	124
Cotton cloth, bleach and dye	100 lb. raw material	1,111.3	6,159.9	115
Paper—sulphate pulp	1 ton pulp product	1,315.4	647,741.0	13,000
General paper mill	1 ton paper product	19,504.8	29,937.6	780
Straw board	1 ton product	5,715.4	151,502.4	2,500
Tanning	1 skin	163.3	1,261.0	22
Creamery†	100 lbs. butter fat	0.90	7.90	14
Corn products† refining	100 bushels			500

* Adopted from table 46, United States Public Health Service Bulletin, No. 143.

† Estimated from a number of analyses.

As a matter of historic interest only, it may be stated that, in the production of one barrel of distillery product, the waste produced is equivalent to the sewage from approximately 50 persons.

Generally speaking, therefore, it is possible to convert the pollution by trade wastes into its equivalent in sanitary sewage and from this figure to determine the required dilution or treatment necessary to prevent pollution. The dissolved oxygen in stream water will vary from approximately 14 p.p.m. at 35°F. to approximately 9 p.p.m. at 70°F., provided the stream is not already polluted and therefore less nuisance is caused by a given amount of sewage in equal amounts of water in winter than in summer.

From the above stated figure of 2204 pounds which represents the daily amount of oxygen required to mineralize the sewage from 10,000 persons, and assuming that 5 p.p.m. of oxygen may be given up by the stream at any time without causing serious nuisance or damage to fish life, it may be estimated that a flow of 80 cubic feet per second or 8 cubic feet per second per 1000 population will be ample for dilution. Such calculations are misleading, however, and cannot be generally applied, since, so much depends on the local condition of the stream. In the past some authorities have stated that a flow of 4 cubic feet per capita is ample, while recently the Royal Commission in England has recommended a dilution of 27.8 cubic feet per second per 1000 persons.

Self purifications of streams is a factor in this problem, but is badly misunderstood. For instance, we have often heard the statement that the Missouri River purifies itself in 7 miles, but this may or may not be the case. Self purification is a factor of time, since certain chemical and biological changes must take place and, therefore, the velocity of the stream, its turbidity, turbulence and other factors must be considered.

Langdon Pearse states that the Illinois River on one test absorbed 205,000 pounds of oxygen from the air while flowing a distance of 65 miles, which fact merely shows that oxygen for self purification can and does come from the air, but this figure cannot be considered for general application, since it represents a certain set of conditions which may or may not be duplicated elsewhere.

Ohio River pollution studies by the United States Public Health Service show that the time of flow from Pittsburgh to the Mississippi River may be anything from 14 to 129 days, depending on the river stages, which fact again emphasizes the point that each instance of pollution is a problem in itself.

This is a very sketchy outline of some of the features of the stream pollution problem, but it serves to show that streams have a definite capacity for biological disposal of sewage and trade waste and that, if the municipalities, and other sewage or trade waste contributors along the stream, control the amount of pollution which they contribute, by properly designed and operated sewage disposal plants, the streams can be kept in good condition, not only as regards nuisance, but with respect to water supply, fish life and other features.

The solution of this problem is obvious and calls for:

1. Treatment of sewage and trade wastes at their source, to an extent to be determined in each individual case.
2. Maintenance and careful operation of sewerage systems and disposal plants.
3. Purification of water at intakes of water supplies, to the extent necessary for safety.
4. Careful operation of water purification plants.

This requires the determination of the extent of purification needed at both ends of the line and for this information we must rely upon information gotten by the federal and state health authorities, who are doing immensely valuable work along this line, and deserve better support from the public than they have received in the past.

Organizations such as the Isaak Walton League are working toward the return of our streams to their original purity and that the problem is being recognized by legislators is evidenced by laws in nearly every state. It is doubtful, however, if this problem can be solved by legislation alone. The solution will probably come only when the public as a whole realizes just how far its welfare depends on proper protection of our streams. When this occurs, prompt action by local organizations will be taken to the end that the necessary work be done.

EQUITABLE CHARGES FOR AUTOMATIC SPRINKLER CONNECTIONS[1]

By William Cartwright[2]

This is not the first time the question of charges for connection to automatic sprinklers from public mains has been discussed in the meetings of this Association, but so far as I know it is the first time that a large insurance organization like the Board of Fire Underwriters of the Pacific has been privileged to offer you its views on this important subject.

As the Board is an impartial body, and disinterested in the financial arrangements between water companies and their customers, I feel confident it will not be suspected of self-interested motives. On the other hand, I believe the experience of the Board on fire protection in general and on automatic sprinkler systems in particular will qualify it to speak on some aspects of the subject from a different point of view.

It is generally recognized that a public water system has only two major functions, namely;

a. To supply water for domestic and industrial purposes, and

b. To supply water for the extinguishing of fire.

It must also be accepted that, if a water system is to meet fully all its obligations, it must be capable of supplying both these demands.

I think that speakers on this subject have not always recognized the automatic sprinkler system as coming within the latter class, and some rate schedules even make no distinction between connections to serve automatic sprinklers and connections to serve ordinary domestic purposes.

The relation of automatic sprinkler systems to the water system largely hinges on its manner of operation. Unlike most other fire extinguishers it is set in motion by the fire itself and without the aid of any human agency, and it usually happens that the fire is extinguished at its very inception by the opening of one or two heads, and to the accompaniment of a very audible water flow alarm. This almost invariably means that very little water is used in extinguishing the fire, and the water flow alarm ensures the water being turned off the system at the control valve as soon as the fire is out. On the other hand it is safe to say that in the absence of a sprinkler system the fire would not be discovered until well under way, and in the unavoidable delay of getting the fire department apparatus at work it will have reached much more serious proportions. Very often enormous quantities of water are necessary to extinguish the fire, all of which is furnished free of charge.

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[1] Presented before the California Section meeting, October 28, 1926.

[2] Engineer, Board of Fire Underwriters of the Pacific, San Francisco, California.

It is sometimes held that "Readiness-to-Serve" justifies a high annual charge for a sprinkler connection, or that such a charge is proper on the grounds that it confers on the user the advantage of lower insurance rates. Every property owner is entitled to fire protection from the public mains without any cost other than his ordinary contribution to the general tax levy. In the case of private water companies a part of this tax is passed on to them, and in return the water company, whether privately or publicly owned, provides water for fire extinguishment, and street mains of adequate size for the fire demand. The "Ready-to-Serve" feature exists already in the obligation of the water utility to provide water for general fire purposes, and, if a property owner provides, at his own expense, a way of taking the water to which he is already entitled and applying it to the fire through a more efficient and economical means than street hydrants provide, he has contributed no additional burden or expense to the water company, but has on the other hand considerably lessened it.

Neither should the value or benefit to the user be the measure of the charge he should bear. Indeed this argument introduces an entirely new principle, which, if consistently applied, would necessitate schedules based upon the uses all consumers made of the water and the profits they derived from it. It would be improper to deny that the normal condition of any building is one in which all fire hazards are properly cared for, and for which a relatively low insurance rate is, quite properly, charged. An unsprinklered building is a risk in which the owner has neglected to avail himself of the fullest degree of fire protection, and for this abnormal condition he is penalized by being called upon to pay a larger insurance premium than he otherwise would.

It is not always the case, however, that the property owner would, by installing automatic sprinklers, save enough to enable him to pay a large annual charge for the water connection in addition to interest on his investment and an installment to wipe out the capital cost. Indeed sprinkler protection appears to have been developed to the point where most of the plants which show a large insurance saving are already sprinklered. There is, too, a large class where the saving will never pay for the cost of protection, but in between these two there is a very large number of risks where the saving which might accrue is entirely swallowed up by the water works charges, or the residue is so small as to be unattractive to the owner. Risks of this class constitute the large majority of commercial buildings and from a fire loss point of view they contain the most potential hazard both as individual fires and as conflagration starting points.

If then it is conceded that every property owner is entitled to water for fire extinguishment without direct payment for the same, the need for a meter in the water connection is not apparent, and can be justified only as a means of detecting a surreptitious use of water for other purposes than the legitimate and special function for which it is furnished. If this theft of water is taking place it is criminal, and as such is a matter for the police department, and not the water company, to take care of. The remedy does not lie in imposing a general and prohibitive requirement upon every owner of sprinklered property, be he guilty or innocent. Mr. George W. Booth, Chief Engineer of the National Board of Fire Underwriters, has stated

> It is our opinion that sprinkler system services, through which no water is drawn except for use in connection with fire protection, should not be metered. There is normally no draft through them, and we believe that it is possible to prevent the illicit use of water by other and simpler means than the installation of meters. These devices add to the expense and likewise to the friction loss in the supply line; some types of meters also introduce the probability of clogging or entirely cutting off the supply by foreign material which may be in the pipe.

A weighted check valve with a smaller meter in a by-pass, in conjunction with the water flow alarm system of the sprinkler installation, would offer sufficient safeguard against the possibility of water stealing. Frequent inspection of all sprinkler systems is made by insurance organizations and these could, if necessary, be supplemented by independent inspection by the water company at the expense of the property owner. This system has been adopted in some cities and is apparently giving satisfaction.

Apart from the loss an individual property owner may suffer from a fire, I think there is another and larger aspect of the case we should consider. A fire is a large irrevocable loss to the whole community. Our own insurance premiums will have to be kept high enough to enable the insurance companies to reimburse the owner, and the municipal and state taxes which he formerly paid will have to be made up by the rest of us. A destructive fire will cause large plants to close down or perhaps go out of business and leave their employees without means of livelihood. The owner of sprinklered property has materially decreased the likelihood of such a catastrophe. Labor will benefit by its greater assurance of continuous employment. The danger to human life will be diminished. Fire departments will be relieved of a large portion of their arduous work, and less demand will be made on the public utility providing water. He ceases to be a serious fire exposure to the surrounding property, for it is a fact that a conflagration never started in a sprinklered building; and he has set up a fire break or conflagration barrier in the event a fire has started elsewhere in the neighborhood. New York is considered by experts a city immune from conflagrations on account of the barriers set up by sprinklered buildings.

I mention these incalculable public benefits to be derived from sprinkler protection, because I believe that this status of the automatic sprinkler is a most important factor and justifies its recognition as in a class entirely distinct from industrial or domestic uses of water.

The recent publication by the National Board of Fire Underwriters of the fire losses in America for 1925 brings me to the last point on which I will ask you to hear me. Over 570 million dollars of property and thousands of lives were sacrifices to fire. It is to be expected in the natural course of events that there should be an increase in our fire losses. New processes in the manufacture and handling of the goods which serve the changing needs of our civilization have increased enormously the fire hazards attending them. Gasoline for instance was, only a few years ago, a by-product in the manufacture of kerosene, but is now in general use for many industrial purposes, and has increased the fire waste tremendously.

If we conscientiously strive to prevent these increasing hazards from making further additions to the annual fire waste, we must make it a matter of public duty to help in discouraging any condition which tends to destroy the interest of the property owner in equipping his building for the reduction of the fire peril.

The Pacific Coast Association of Fire Chiefs at its annual meeting last year expressed its feeling on this subject by passing the following resolution

> Whereas this association is of opinion that automatic sprinklers are a public benefit, in that they have proved to be an efficient means of fire extinguishment and in that they tend to conserve human life, wealth and property from disastrous fire, and
>
> Whereas it is believed that an automatic sprinkler system does not increase the demand on the public utility providing water, but instead tends to decrease it
>
> It is the Desire of this Association to encourage the installation of automatic sprinklers, and to discourage high monthly charges for connection from public mains to automatic sprinkler systems, provided the individual or individuals receiving this service assume the entire cost of the installation and maintenance of the connection.

High charges for sprinkler connections are a serious deterrent to the enterprise of property owners in making proper provision for the safety of their premises, and our attitude to this question will largely be the measure of our conception of the ideals of good citizenship.

IRON REMOVAL PLANT AT SELMA, ALABAMA[1]

By J. A. Fulkman[2] and E. J. Taylor[2]

The City of Selma, Alabama, has a population of 18,000. The water works system is owned by the city and operated by a commission elected by the city council. The railroads and practically all of the industries have their own wells, so that the public supply is used almost exclusively for domestic purposes.

For a number of years the consumers have been annoyed by "red water." In November, 1924, the water works commission decided to have an investigation of the underlying cause of this trouble, and what could be done for its elimination. This disclosed that the iron in the water which was causing the trouble could be removed by aeration, sedimentation, coagulation and filtration through rapid sand filters. The construction of a plant of 1,500,000 gallons daily capacity was started in September 1925 and operation commenced in May 1926. The description of these works follows.

SOURCE OF SUPPLY

The water is obtained from artesian wells. The main supply being a 10-inch well, 450 feet deep. The water level under continuous pumping is about 30 feet below the ground surface. A Worthington "Axiflow" pump, directly connected to a 50-horse-power electric motor is used to pump this well. This pump is controlled by a float switch connected to the settling basins. It discharges 1,250,000 gallons per day against a total head of approximately 40 feet, or sufficient to carry the water through the new plant. There is also an auxiliary and emergency supply consisting of five 6-inch wells; which are also about 450 feet deep. These are pumped by air lift; the compressor being operated by steam. The combined discharge of these wells is 1,500,000 gallons per day.

The water, when pumped from the wells, is clear and is safe for drinking, but contains 18 parts per million of free carbon dioxide and

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[1] Presented before the Central States Section meeting, September 22, 1926.

[2] With Morris Knowles, Inc., Engineers, Pittsburgh, Pa.

2 parts per million of iron. When this water is exposed to the air the soluble iron compounds are oxidized and the water becomes cloudy and brownish in color. It also stains the plumbing fixtures and forms a sludge in the mains which has caused considerable dissatisfaction.

SPRAY NOZZLE AERATORS

Spray nozzle aerators are connected to the raw water lines from the wells. Two sets of nozzles are provided, each set consisting of eight 2-inch "Sacramento" nozzles, manufactured by the Water Works Supply Company of San Francisco, California.

Each nozzle is designed to deliver 75 gallons per minute with a 5-foot loss of head. They were found to give an efficient and satisfactory spray with as low as 3-foot head. The water from the nozzles falls on a slightly inclined concrete slab and flows to the influent end of the settling basin.

SETTLING BASINS

Two settling basins are provided; one under each set of nozzles. Each basin has a capacity of 190,000 gallons. This gives a combined capacity of 380,000 gallons and a retention period of about six hours, at the normal rate of 1,500,000 gallons per day. This settling period may be somewhat longer than necessary, but was provided on account of remodelling an existing reservoir for settling purposes. An around-the-end-baffle is provided in each basin. A velocity of 0.25 foot per minute is maintained when operating at the normal rate. The piping is so arranged that the basins can be operated separately or together as desired. High pressure lines and hose valves and drains are provided for cleaning the basins.

MIXING CHAMBERS

Although the preliminary experiments indicated that satisfactory results could probably be obtained by aeration, sedimentation and filtration only, it was deemed advisable to provide for the addition of lime and alum or iron sulphate. Two dry feed machines are located on the second floor of the control and chemical house. Each machine is so connected that it will feed to the two mixing chambers, located on the first floor of this building.

The mixing chambers are circular concrete tanks 10 feet in diameter and 10 feet deep, giving a mixing period of ten minutes at the normal rate of 1,500,000 gallons per day. Mechanical agitators are provided, consisting of a vertical shaft directly connected to a one horse power motor, making 860 revolutions per minute. Two 11-inch, two-blade propellers are fixed to the shaft. The bottom propeller, located five feet above the tank floor, deflects the water upward, while the other propeller, located 6 feet above the tank floor, deflects the water downward. The influent pipe is located 1 foot above the floor of the chamber and the effluent pipe is on the opposite side of the tank 5 feet above the floor. This arrangement proved satisfactory, the agitation being quite thorough throughout the tank. The chemical treatment, if and when used, is to be applied after sedimentation. It was therefore necessary to provide coagulation basins ahead of the filters. Provision is also made for taking the raw water from the wells directly to the mixing chambers, thence to the settling basin as in the ordinary filtration plant.

LIME BASINS

There are two coagulation or lime basins provided. Each basin has a capacity of 35,000 gallons, giving a detention period of 1.1 hours at the normal rate of 1,500,000 gallons per day. Wooden over and under baffles were installed in these basins to give a velocity of 0.1 foot per second. When the mixing chambers and coagulation basins are not used the settled water can be taken directly to the filters.

FILTERS

Three one-half million gallons per day filter units were installed in a separate building. The filters are reinforced concrete boxes, 15 feet by 12 feet by 9 feet deep. The under drainage system consists of a 12 inch by 18 inch concrete flume, built under the filter floor, in which are inserted 2½-inch by 2½-inch by 3½-inch cast iron tees, 7 inches on centers. Cast iron laterals, 2½ inches in diameter, with ¼-inch holes in the bottom, 45 degrees from the vertical, extend across the filter from these tees. They are placed 1½ inches above the filter floor and the wall ends are set in cement grout.

The filter bed consists of 18 inches of gravel, graded from 1¾ inches to $\frac{1}{12}$ inch in diameter, overlaid with 30 inches of sand, having an effective size of 0.37 mm. and a uniformity coefficient of 1.7. The high uniformity coefficient was allowed because the precipitate was fine. All filter valves are hydraulically operated from operating tables on the operating floor above the pipe gallery. Venturi type rate controllers are used, with indicating and recording rate of flow and loss of head gauges mounted on the operating tables.

The wash water troughs are reinforced concrete, placed 24 inches above the sand. The wash water is supplied from a 40,000 gallon elevated steel tank, at a pressure varying from 22 pounds per square inch to 15 pounds per square inch. This gives a maximum rise of 24 inches per minute in the filters during washing. The preliminary operation indicated that best results were obtained by washing the filters when they showed a loss of head of about 6 feet. Each unit would filter about one million gallons and requires about 20,000 gallons for washing. Thus only 2 per cent of the water filtered is used for washing.

RESULTS OF PRELIMINARY OPERATION

The plant was first operated with water from the electric-pumped well, using aeration, sedimentation and filtration only. The raw water contained 18 parts per million of free carbon dioxide and 2 parts per million of iron. The free carbon dioxide was reduced to 6 parts per million in the aerators. After sedimentation the free carbon dioxide content was found to be 3 parts per million and the iron content 1.1 parts per million. The precipitate was fine, being practically invisible to the naked eye. However, it failed to pass the filters and the filtered water showed 3 parts per million of free carbon dioxide and only 0.25 part per million of iron.

When the plant was operated with the air lift wells the reduction of free carbon dioxide was practically the same and the reduction of iron in the settling basin was also the same. However, the filtered water showed only 0.15 parts per million of iron. This was attributed to the better aeration. It was found that the free carbon dioxide was down to 3 parts per million at the aerators against 6 parts per million for the electric pumped well.

The plant was also operated with the addition of lime after sedimentation, to completely remove the carbon dioxide. This was added at the rate of 15 pounds per million gallons per part per million of free carbon dioxide. Since there were 3 parts per million of carbon dioxide present after sedimentation it required 45 pounds of lime per million gallons. There was no appreciable reduction of iron in the coagulation basin, but the filtered water showed the carbon dioxide removal to be complete. The iron content was only 0.06 part per million. The alkalinity to phenolphthalein was only 4 and to methyl orange 80. The alkalinity to methyl orange in the raw water was 79.

An iron content of 0.25 part per million and a carbon dioxide content of 3 parts per million was considered satisfactory. The filtered water was found to be non-corrosive, giving pH 8.6. The plant is therefore operating with aeration, sedimentation and filtration.

There was at first considerable doubt among the citizens concerning the plant. Some did not think it would work and others expected to find the water "flat" for drinking. The plant was therefore first operated without an announcement. After six hours the difference could be plainly seen in the tap water and in three days everyone was remarking about the clear water. Plumbing fixtures once cleaned stayed that way—shower bath curtains failed to turn red the second day they were used and no one found the water flat. At the time of the inspection by the Mayor and Council the latter part of May it was unanimously decided that it was the best $65,000 the City of Selma had spent in years.

The report by H. G. Menke, of the Alabama State Board of Health, made after preliminary operation, contained the following:

> The deferrization plant of the City of Selma is very complete and flexible. Every possible foreseen operation has been provided for, so that almost any condition of water may be satisfactorily treated. The adaptation of new work to old was nicely accomplished and the plant presents a pleasing appearance.
>
> Selma's water supply has been unsatisfactory from a physical standpoint because of iron. With the new work completed no further trouble should occur from this source. The water with good operation of the plant should always be clean and sparkling and practically free from iron.

The writer visited the plant the latter part of August and it was then producing a very satisfactory water. The foreman of the distribution system stated that they did not have any further trouble with the water running rusty for several hours after opening a main for repairs or additional connections as they had before the iron removal plant was put into operation.

The Smith Company, of Birmingham, Alabama, were the contractors for the structural work; the McFarland Engineering Company, of Kansas City, Mo., for the filter equipment; and R. D. Cole Company, of Newman, Ga., for the wash water tank. E. J. Taylor was resident engineer for Morris Knowles, Inc., during the construction of the plant. Albert Thalheimer is President and Robert Coleman, Manager of the Water Works Commission. Much credit is due them for the short time that elapsed between the investigation as to what should be done to eliminate the "red water trouble," and the completion of the iron removal plant.

THE FRANCHISE OF THE CITIZENS WATER COMPANY, BURLINGTON, IOWA[1]

By Francis D. H. Lawlor[2]

The Burlington Water Company was incorporated for a period of twenty-five years in 1877. The first water ordinance was adopted by the City Council July 17, 1877. It provided that the cost of the water works should not exceed two hundred thousand dollars and that the plant should be in full operation within one year with 10 miles of water mains and 150 fire hydrants; that the works have a capacity of three millions gallons daily and be capable of throwing six streams to a height of 75 feet through inch nozzles on the high ground or eight streams through inch nozzles to a height of 100 feet on the low ground.

The capital stock of the company was fixed at three hundred thousand dollars, not more then 10 per cent to be paid up at that time. A bond issue of two hundred thousand dollars was authorized and an annual dividend of 12 per cent on the paid up stock was allowed.

The City had the option to purchase the plant by giving a year's notice in writing at the beginning of any year. This right was not exercised until the franchise of the water company expired in 1902.

The plant was originally built by the Holly Manufacturing Company and had one Holly quadruplex pumping engine of three million gallons daily capacity. Extensions of mains were made from time to time during the life of the franchise. In 1902 the Company had about 22 miles of cast-iron mains. About 1884 a second pumping engine, a Holly Gaskill of three million gallons capacity was installed. In 1893 and 1894 a larger Holly Gaskill of six million gallons daily capacity was purchased, a filter house was built and the original type of Jewell gravity filters were placed therein. The filtered water was stored in a masonry basin below the filters.

Strained relations existed for many years between the Burlington Water Company and successive City Councils.

[1] Presented before Iowa Section meeting, November 4, 1926.

[2] Superintendent, Citizens Water Company, Burlington, Ia.

When the franchise expired in 1902 the City, not being in a position to finance the purchase of the plant, a number of citizens organized the Citizens Water Company to accomplish this object.

The ordinance of the Citizens Water Company was approved and accepted October 10, 1902. It was found the City had acquired sixty-five thousand dollars of the bonds of the Burlington Water Company. In lieu thereof it was given that amount of the common stock of the new Company.

During the years that have elapsed since 1902 the City has taken its six per cent dividends on this common stock and reinvested them in the securities of the Citizens Water Company. To-day it holds about one hundred and seventy or one hundred and eighty thousand dollars of the stock or bonds of the Company.

Policemen and firemen pension funds have also been invested in the same securities.

Section 4 of the ordinance provides that the Company may be required to extend its mains along graded streets provided the revenue is sufficient to pay 6 per cent annually on the cost of the work.

If the Company is required to extend its mains along streets that are not at grade the City pays the cost of lowering the mains when the streets are graded.

The extension of mains required is limited to 3 miles each year for the first and second years and to 2 miles each year thereafter.

Under this provision of the ordinance the distribution system has grown from the original 10 miles of mains and 150 fire hydrants to 65 miles of mains and 630 fire hydrants.

In recent years our difficulty has been to find streets that will pay the 6 per cent interest on the present costs for our water rates are much the same as forty-nine years ago.

During the last few years we have introduced a form of contract to enable contractors or promoters to have water mains laid in new additions by guaranteeing the 6 per cent revenue for a term of ten years and by depositing Liberty Bonds or cash to secure the guarantee. We give the guarantor an accounting each year and deduct the deficit each year from his guarantee fund.

Whenever the street pays the 6 per cent we refund the balance of the guarantee fund and close out the account. In a few instances we figured the guarantee fund too low or to speak more correctly we overestimated the annual revenue the street would pay.

Under section 9 the City levies a five-mill tax on the dollar on all the property, real and personal, in the established water district. This tax now yields in round figures twenty-eight thousand dollars per annum. The interest on the bonds of the Company, which is guaranteed by the City, is the first claim on this tax. The proceeds of the five-mill tax go to the treasury of the Water Company and constitute the payment by the city for water supplied for fire protection, for flushing sewers and other public uses for which City does not pay in any other way.

Section 10 fixes the capital stock of the Company at three hundred and thirty thousand dollars, viz., $150,000.00 common stock carrying 6 per cent dividends payable semi-annually and $180,000.00, preferred stock allowed 5 per cent dividends, also payable semi-annually. The preferred stock may be retired.

A bond issue of two hundred and twenty thousand dollars was authorized, but only one hundred and eighty thousand dollars of the bonds were sold and of this amount sixty thousand dollars were purchased during the world war and placed in the Treasury for emergencies.

Section 14 provides the City may purchase the water works by giving a year's notice in writing, by buying the stock at par and by assuming all the other liabilities of the Company.

Section 16 provides for a board of five directors two appointed by the Mayor and three elected by the stockholders each year.

Section 18 provides for arbitration between the City and the Water Company in the event of disagreement.

Section 19 requires semi-annual reports of all receipts and expenditures to be made to the City.

Section 21 provides that the Company may fix its own rates, but no such charges shall be greater than shall be found prevailing in some of the cities of Des Moines, Davenport, Muscatine, Clinton or Cedar Rapids in this State.

We now have 6970 active services of which only 450 are metered. Burlington is a flat rate city with a population of 26,200 and a daily consumption of about 105 gallons per capita.

The relations between the Water Company and the City have been very amicable during the past twenty-four years. The public realize that no salaries are allowed except those of the Secretary and the Superintendent and their subordinates, that no Director or stockholder of the Water Company can receive anything more than the regular dividends allowed by the franchise and that all surplus monies accumulated are spent on the improvement of the plant.

The proceeds of the bond issue were used in making improvements needed immediately after the organization of the Citizens Water Company. Since that time approximately fifty thousand dollars has been spent annually on extensions, improvements and betterments, all of which have been made from earnings.

Alvord & Burdick made an inventory and report upon the value of the properties of the Water Company as of January 1, 1916, basing their figures on an average cost of labor and materials over a term of years previous to 1916. They placed the value of the property as of that date, in round numbers as nine hundred and sixty thousand dollars, exclusive of operating capital. Their figures were based on prewar prices. During recent years the expenditures on capital account have been much greater than the depreciation.

Looking back over the twenty-four years since the organization of the Company, we believe we can truthfully say the ordinance has considerable merit and that it is one way to attain the advantages of municipal ownership in combination with those incidental to private management.

Whatever success has been attained in Burlington may be attributed to the hearty coöperation of the City and to the fairness and public spirit which has animated both parties to the contract.

DISINFECTION OF NEW WATER MAINS[1]

By William W. Brush[2]

It has been our practice for a great many years to require a certain amount of hypochlorite of lime to be placed in the pipes as they are laid. The requirements specified for cleaning pipes and for chloride of lime read as follows:

> 7: Cleaning pipes, etc. All straight pipes and special castings shall be cleaned by brushing and by thoroughly washing out all dirt or all foreign material before laying. To prevent any foreign matter entering the main as the pipe laying proceeds, if the engineer so directs, a proper mandrel shall be provided by the contractor which shall be drawn forward as each pipe or special casting is laid. All branches and other openings shall be stopped up by wooden plugs or heads until either connected or capped.
>
> 8: Chloride of lime. As each length of pipe is laid, the contractor shall furnish and deposit in each length one-half ounce of chloride of lime. The contractor shall furnish and place said chloride of lime, the cost of same to be included in the prices bid for laying pipes. Instead of placing the chloride of lime in each length of pipe, the contractor may deposit same on each side of the valve in the main line in a sufficient quantity for the length of pipe between valves.

You can readily see the way in which it is expected that this chloride of lime will act in sterilizing the main. After the main has been laid between two valves, a valve at one end is opened to let the water pass into the main and over the chloride of lime which is dissolved and sterilizes the main. After the main is filled, it is thoroughly blown out and a sample of the water taken and sent to the laboratory to be examined for the bacterial contents. Usually we find that only one blowing out of the main is necessary to get a water that is satisfactory, but at times we have had to blow out a main three or four times, and after each time it was blown out a sample was sent to the laboratory. As near as I can determine the additional blowing off of the main is due to the accumulation of mud in the pipe, as the chlorine will not effectively sterilize below the surface of the sediment that is in the main. Just to what extent the sterilization will take place below the surface of sediment I do not know, but from experience during the past year I am inclined to think that the chlorine penetrates only slightly below the surface. It appears therefore that it is very important that the surface of the pipe should be free from any accumulation of sediment when the pipe is laid, and if that be the case a very small amount of chlorine will be all that is necessary to sterilize the interior of the main. Fortunately the sediment that gets in the pipe is usually of a character that is not likely to be detrimental to the health of human beings, but it is not a pleasant thought to lay pipes and put water through them and send the water to the consumer if the water comes in contact with what we would commonly term filth.

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[1] Discussion presented before the Buffalo Convention, June 11, 1926.

[2] Deputy Chief Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

A year ago we had to lay a pipe in the Rockaways just before the opening of the summer season. It went through the only street that was paved for automobile traffic, so that if the work continued into the relatively short summer season, it would seriously interfere with the business season of the merchants and hotel men in the Rockaways, the Rockaways being part of our borough of Queens, and the southeastern corner of the city of New York. Our contractor had a twenty-four inch main to lay, and for the greater part of the distance it was below the water level in a sand which was virtually very fine beach sand. The sewer system was noted more for the openness than for the tightness of its joints, with the pipes only about four feet below the surface. As a result when the tide rose, the sewage backed up in the pipe and in part seeped out and polluted the sand in the vicinity. When the tide fell the sewage again flowed out into the bay or ocean. We therefore had a polluted sand and a polluted ground water, and it was impossible to get the trench free from water, so that the water pipes were at times completely immersed in a polluted water and quite a good deal of polluted sand was washed into the pipes.

After the pipes were laid and tested the volume of water available was not sufficient to blow the sand out because one part of our connecting line to the city system was not completed and we could only take a small amount of water from the local company. We added chlorine gas to the water flowing into the main until we had three parts of residual chlorine per million in the water at the further end of the pipe line. That high chlorine content water was held in the pipe line, as I recall, for some twenty-four hours, and then flushed out, and we thought that we would have a reasonably safe line. We sent a sample to the laboratory and got a satisfactory report, although the water was not quite as good as we would like to have had it, and we started to use the line. Within a day or so we had complaints of tarry taste due to the chlorine attacking the coal tar coating, and, what was much more disturbing, the laboratory reported the bacterial content to be high. The line was immediately shut off and it was found that it was impossible to get that line safe to use until we could use the city supply and flush it out with a velocity of six or eight feet a second. Even with that velocity we had to flush it out three times running for several hours each time before we could get the sand out of the pipes, and the joints in the pipe, sufficiently to give us a sterile line after chlorination. In order to get that high velocity, we had to open up a thirty inch branch to the bay, and let the thirty inch branch deliver at full flow during the time we were washing out the main. That experience brought home to us very, very strongly the fact that you cannot have polluting material in your pipe and be safe in using that pipe, because you cannot get the chlorine to penetrate the material that is in the bottom of the pipe. I am glad to be able to bring this experience to you, believing that if you ever have a similar situation our experience may save you the very uncomfortable days that we had after we knew that pipe line had been used and later found to be in an unsatisfactory condition. As a matter of fact, there was no illness that could be attributed to the use of that pipe except some slight stomach disturbances.

DISCUSSION

Mr. Lane: I want to ask about the quantity used; was it half an ounce per length? Was that right?

Wm. W. Brush:[2] In our regular specifications, which cover usually pipe up to 12 inches, it is half an ounce of chloride of lime to each length.

Mr. Lane: Does it make any difference regarding the size of the pipe?

Wm. W. Brush:[2] It probably would, although my recollection is the half ounce gives a pretty high chlorine content to the water.

B. C. LITTLE:[3] I am anxious to know what led you to sterilize your mains and how long you had been doing this? I will have to confess that we have never done it in Rochester. From the experience you know of in other cities, has there been such sterilizing of the mains?

WM. W. BRUSH:[2] My recollection is that we started about twenty years ago. We started because it seemed to us that a pipe that has been lying on the street without any protection for possibly a period of several weeks or several days, is not a clean utensil for a conduit through which to pass water that is to be used for drinking. We first started to put in the chloride of lime and blow out the pipes without sending the samples to the laboratory. Then we concluded that it was not very reasonable to do it somewhat blindly when we had our laboratory there and we started the practice of sending the samples to the laboratory. Our experience has indicated the desirability of so doing, because it has shown us the cases where we did not get satisfactory results. It has been the cause, I believe, of more care on the part of our construction group in looking after the cleaning of the mains as they are laid.

The pipe should be clean when the water passes through it to the consumer and we know it is not clean as it lies in the street. We ought to wash it out thoroughly, and it only seems a reasonable precaution to put a sterilizing agent in that pipe before we let the water reach the consumer.

B. C. LITTLE:[3] You have not answered one question I meant to ask; have you any statistics as to the custom in other cities?

WM. W. BRUSH:[2] I personally do not know that I can answer with any certainty as to the custom. I have had it brought to my attention that some other cities do follow a practice somewhat similar to ours, but I could not at the present time name those cities. I would be glad to have those present indicate to us, assuming we do have those present who blow out the mains before they put them into service. I will ask them to please raise their hands. Well, there are quite a number who do that. Now, how many put any sterilizing agent in? There are two, Mr. McDowell and Mr. Lane, of St. Petersburg, Fla.

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[3] Secretary, American Water Works Association, Rochester, N. Y.

MR. LANE: While you are having your laboratory samples tested, do you put the main into service or leave it out of service until after you get the report?

WM. W. BRUSH:[2] We leave it out of service until after we get the report. If we are replacing a main and there is no way of avoiding the immediate use of the main, we blow thoroughly and put it into service, but when we are extending mains, we leave them out of service until we get the laboratory report that the water is satisfactory. If it is not satisfactory, we blow the main again. We do not try to sterilize a second time, other than in unusual situations such as described for the Rockaways. After the first introduction of chloride of lime, we depend upon blowing and the removal of any sediment in that manner.

PHIL CARLIN:[4] Do you have any specified time for this water to remain in the mains before it gets into the general system?

WM. W. BRUSH:[2] No, Mr. Carlin, usually it is an extension of the system and therefore the water would not go into the general system; it would go to the building to be connected. It takes our laboratory forty-eight hours before they are willing to give a report, because of the usual three day test for B. coli, but if the laboratory gets a negative on twenty-four and then again a negative on forty-eight hours, and there is any need to hurry up a little on putting the main into service, we open up the main for service.

MR. LANE: We began the chlorinating of the pipes about a year ago. We were led to do that because ours is a very flat country and a good part of it had no sewers in it. A great many septic tanks were in use, and in putting in these new mains, it seemed possible, especially in going through muck land, that the mains would be so contaminated that the water would not be fit for use, so we thought it was best to use lime. We let the water stand twenty-four hours until our local sanitary board has examined it, and if that examination is satisfactory, the pipe is put into service.

[4] Superintendent, Water Works, Sioux City, Iowa.

H. P. Bohmann:[5] I was wondering how you insert the hypochlorite if the line needs a second treatment, after you have blown out the line and find it necessary to give a second application?

Wm. W. Brush:[2] We used the liquid chlorine, and we insert it through a tap in the main. There is a small portable machine that was made up by Wallace & Tiernan Company that we have used. The details of that machine I do not know, as I have never seen it actually in operation in the field. I do not recall any of my men explaining to me exactly the details of that machine, but it is a small portable machine and we had to guess somewhat at the rate at which the chlorine was going in. What we do is this, we take water at the nearest hydrant and test for residual chlorine and then we set the flow of chlorine so as to get at least as high as we have fixed as the minimum free chlorine. In the case of the Rockaway main we had three parts of free chlorine at our furthest hydrant and we had five parts at the hydrant nearest the point of introduction of the chlorine. The furthest point was a couple of miles away. Still it was evidently only the surface of the sand that was sterilized by that strong chlorine treatment, as within about two days, the bacteria in the sand had worked up to the surface and the water that was drawn showed in some places as high as 500 bacteria. That result was after the chlorinated water had been drawn off and other water introduced at a rate which probably did not disturb the sand, because we tried to keep the flow down to the point where it would not disturb the sediment left in the pipe. We intended to use this pipe only temporarily to meet a very serious shortage of pressure, and had planned to blow it out thoroughly as soon as our own system was available, but we had to cut it off and leave it off until we could get our own flow through the pipe.

Mr. McDowell: Such a condition as Mr. Lane had prompted us to use hypochlorite of lime for sterilizing new mains and old mains that were replaced by new mains. Charleston has low lying ground. In some portions of the city it is necessary to wait until low tide to lay the mains. With the tide coming in and flooding the mains in course of construction, it brings the filth into the mains. Therefore, we started sterilizing the mains.

[5] Superintendent, Water Works, Milwaukee, Wis.

L. H. Enslow:[6] The research work being done by the Chlorine Institute on chlorination of sewage confirms exactly your supposition that the bacteria are protected. Chlorine, we find, will not penetrate a solid body. Therefore, it is not to be considered efficacious in the presence of large particles of solid matter. It seems that the outside surface of the solids are seared by the chlorine, and whether or not a protective coating is formed I do not know, but in some water a protective coating forms on the surfaces and the chlorine does not thereafter penetrate. The only way to carry on effective disinfection of solid masses is to create such velocity that it will break those masses up or else get rid of them.

While I am here I might mention a very effective method used in Texas on wells which a company there now drill, and where a combination graval pocket is formed around the strainer in the bottom of the well. The well people had quite a bit of trouble with the bacteria on the new wells. They have found that the only remedy which has been efficient has been a thorough washing of the gravel with clear water and thereafter they get very satisfactory results from the effluent of the well and no B. coli have appeared. That was discovered in Houston, Texas, and I understand now that it has been adopted as a universal practice.

Wm. W. Brush:[2] There is one condition to which I should like to call your attention, which you may or may not have experienced. When you shut down a main and blow off, especially with one of the larger mains, where you use a blow off, probably at the bottom of the pipe, it may be blowing off into a drainage channel that may later fill up if you have a heavy storm. You may get polluted water coming back into your main in that way, or you may have a leak in a pipe and make a shutdown to make a repair, and before you make the repair, you may have a similar situation. Those conditions have been brought to my attention, not alone in our system, but also in the systems of some other municipalities. It is very important, therefore, to keep in mind that, when the main is shut down, there is a possibility of water entering if there is any opening left unguarded. That water may be polluted and at least there should be thorough blowing off of the main. If you think that the water that has entered has been seriously polluted, there ought to be also the sterilization of the main before it is put back in service. You see we cannot tell by typhoid alone as to whether we are furnishing people with water that is unsafe and unsatisfactory, because it is possible that we will only have the intestinal disturbance that comes from other bacteria and will not happen to have any typhoid bacteria in the polluting material in the water that has entered the pipes. As we reach a higher and higher standard for the purity of our water supplies, we are thereby decreasing the amount of intestinal disturbance among our consumers.

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[6] The Chlorine Institute, New York, N. Y.

QUESTION BOX SERIES[1]

CEMENT-LINED PIPE

Philip Burgess:[2] It is a well established fact that tuberculation of pipe lines may be an important element affecting the history and efficiency of distribution systems. Any protective covering which tends to reduce, or eliminate, tuberculation of pipe lines is an important asset insofar as it tends to prolong the useful life and efficiency of a water works distribution system. The common method of attempting to preserve the usefulness of cast iron pipe has been to apply some form of tar or protective coating which may, or may not, be effective, depending upon the chemical characteristics of the water carried in the pipe line system. Experience has shown that such protective coverings are not effective in reducing or eliminating tuberculation of pipes, particularly where the water is soft and highly colored. In the case of such supplies, the pipe lines frequently become obstructed by tubercles which may reduce the carrying capacity of the pipe system by from 20 to 50 per cent within a short period of time. Furthermore experience indicates that, in many instances, the cleaning of such pipe lines is not satisfactory, because, after such cleaning, the tuberculation may form again very rapidly so that all value of the cleaning may disappear in a few weeks. This has been the somewhat universal experience of protective coatings on pipe lines carrying soft highly colored water until the last three or fours years when consideration has been given to the use of cement lining to protect cast iron pipe, where the water is of a character that may cause even a small amount of tuberculation in the pipe lines.

The early history of cement lining for pipe indicates that such linings were used first to protect the inside of wrought iron pipe. Experience indicates that such linings were effective both in reducing tuberculation of the pipe and in increasing the life of the pipe, except in such instances as the pipe was attacked from outside agencies.

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[1] Presented before the Central States Section meeting, September 21, 1926.

[2] Consulting Engineer, Columbus, Ohio.

About three or four years ago, the method of applying cement linings to cast iron pipe was very much improved by the use of a centrifugal process. By this process the pipe containing the liquid cement mortar is spun at a comparatively high velocity with the result that the cement lining is very compact and clings tenaciously to the inside of the pipe. No other protective coating is used inside the pipe except the cement mortar. The thickness of the lining is greatly reduced by the centrifugal process and varies from $\frac{1}{16}$ inch thick for the 4- and 6-inch pipe to $\frac{3}{16}$ inch thick for the 20- and 24-inch pipe. The surface of the lining is very smooth and hard and experience indicates that no especial care in handling the cement lined pipe is necessary in order to avoid damage to the lining. The cost of lining the pipe with cement is from approximately 8 per cent for the 6- to 12-inch sizes to 6 per cent for the 16- to 24-inch sizes, in addition to the cost of the unlined pipe.

As previously stated, the cement linings which have been in use for some time have proven very satisfactory because they have protected the pipe and because they have appeared to eliminate tuberculation and thereby to maintain the carrying capacity of the cement lined pipes. Owing to the fact that the modern centrifugal process of cement lining is only about three years old, there is, of course, no experience extending over a considerable period of time to show whether or not the benefits to be derived from such linings are of a lasting nature. The best available evidence as to the merits of cement lining probably is contained in an article by Charles W. Sherman (Journal of the New England Water Works Association, vol. xl, no. 1) entitled "Cement Lined Cast Iron Pipe." Mr. Sherman's article contains a brief statement as to the known history of cement lined pipe together with specifications for lining the pipe and a statement of the present cost of the lining. An appendix to this paper contains a report by J. E. Gibson, Manager and Engineer of Water Works Department, Charleston, South Carolina, in which report Mr. Gibson sets forth the results of his experiments to determine the coefficient "C" in Hazens and Williams formula for cement lined pipe. In this report are shown the results of three tests of cement lined pipe, two of which were 6-inch diameter and one was 16-inch diameter. In all three tests the value of the coefficient "C" was higher than that commonly adopted for new cast iron pipe covered with the usual protective coating. The results of Mr. Gibson's tests are of interest and seem to indicate clearly that cement lining applied by the centrifugal process increases the carrying capacity of the new pipe as compared with the usual protective coating.

At the conclusion of Mr. Gibson's report he states as follows:

> Our experience, covering a period of about three years, shows that the pipe is not incrustating or tuberculating, the carrying capacity is being maintained, and no difficulty is being experienced in tapping or cutting the pipe. A number of Smith taps have been made where the section cut out by the cutter permits of examination, showing that the cement-lining is tenaciously adhering to the cast iron without tuberculating or rusting underneath the coating.

The writer has sent out a number of inquiries to men in the water works business who were familiar with the use of cement lined pipe and, in each instance, the replies received indicate that it is the general experience that cement lining increases the carrying capacity, not only of cast iron pipe, but also of wrought iron pipe, and that furthermore the cement lining eliminates tuberculation which may be expected to form on the inside of pipes carrying soft colored water. In fact there seems to be developing a pronounced opinion among water works engineers that cement lined pipe should be used wherever the water carried is of a kind that may cause even a moderate amount of tuberculation. Present evidence indicates that cement linings increase the carrying capacity of cast iron pipe when new and tend to reduce, or eliminate, tuberculation which might be expected in time were such pipe lined with the usual protective coatings. There seems to be very good substantiating evidence that these conclusions will be confirmed with continued long time use of the cement lined pipe. We may safely conclude that the benefits to be expected from the cement lining of pipe carrying water which may cause even a small amount of tuberculation more than justify the cost of securing this protection.

CONSUMERS REACTIONS TO VARIOUS SYSTEMS OF RATES

J. H. SIMPSON:[3] Probably I can best make myself understood by describing conditions in rates as they exist at the South Pittsburgh Water Company's plant. The company was chartered in 1904 for the purpose of taking over several small water companies purchased at that time by the old American Water Works & Guarantee Co.

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[3] Treasurer, South Pittsburgh Water Company, Mt. Oliver Sta., Pittsburgh, Pa.

At that time there was in use a rate system under which the consumers contracted annually beginning April 1st of each year for the quantity best suited to their needs (I am speaking mostly of the small or domestic consumers). This schedule was as follows:

40,000 gallons per year $15.00, all water over 40,000 at 33⅓ cents per 1,000 gallons.
60,000 gallons per year $20.00, all water over 60,000 at 30 cents per 1,000 gallons.
100,000 gallons per year $30.00, all water over 100,000 at 25 cents per 1,000 gallons.
180,000 gallons per year $45.00, all water over 180,000 at 20 cents per 1,000 gallons.

We collected the quarterly minimum in advance and made no extra or excess charges until the quantity of water used exceeded the amount contracted for annually. This meant that a 40,000 gallon consumer might use all of the 40,000 gallons in the 3 quarters ending January 1, but no charge for overage or excess would be made until April 1, at which time all of the water used would be charged for at 33⅓ cents per thousand and we would still be billing at the same time the $3.75 quarterly minimum. This created a goodly amount of complaint from the consumers, for many of them could not see the reason for paying the $3.75 if we charged for all the water used in that quarter at the excess rate. They lost sight of the fact that they had used 40,000 gallons, but paid for only 30,000.

This rate schedule ran along until 1920. The company had carried on all during the war period at the old rates with the vain hope that costs would come down after the war and we could make out some way even with the war shrinkage in our net receipts. When the company finally decided that it would have to raise its rates, on account of so much complaint from the consumers about the system I have just described, it was also decided to adopt what is considered the most modern and up to date system of a "ready to serve" charge plus a smaller meter rate. It was decided that a 20 per cent increase would be sufficient at the time and the new rates were put into effect August 1, 1920. It was later found that the new schedule brought us about 17 per cent increase.

This ready to serve system was new in the Pittsburgh territory in so far as use by a water company was concerned and the consumers seemed, to a large extent, unable to understand it. We issued full explanations by letter to all our consumers, giving in detail our reasons for increasing the rates and our reasons for changing to the new system. The feeling of many consumers, as indicated by their oral and written complaints or inquiries (whichever you wish to call them), seems to be that our charge per thousand gallons is what we are entitled to and the ready to serve charge is nothing but graft. Now do not misunderstand me that *most* of our consumers take this attitude. They do not, but when the company has 30,000 consumers to deal with and one is brought into contact with only those who complain, a few hundred seem like a great many.

Many of the consumers seemed unable to grasp the point that it took the meter charge plus the ready to serve charge to produce sufficient revenue to operate the plant and produce a reasonable return for the stockholders.

This ready to serve charge system is similar to the "demand charge" of many electric power companies, but domestic electric consumers, as a rule, do not get into the "demand charge" class so that did not help us much, nor for the same reason did the adoption a little later by the United States Post Office Department of their present system of ready to serve charges for parcel post service.

We have tried consistently, persistently and patiently to explain this system in a way that will make it clear to the ordinary domestic consumer, but have never yet been satisfied that the explanation made the matter clear to a majority of the inquirers.

I have also had at another plant considerable experience with a rate system under which the consumer "pays for what he uses"—with a small minimum. This schedule started at 22 cents per 100 cubic feet or about 30 cents per 1,000 gallons. The minimum was 1.25 per quarter so that it took only 700 cubic feet or 5,000 gallons to absorb the minimum. This rate was so low that I remember few, if any, complaints about it, either as to the rate or the method of calculating the bills.

This rate was increased 25 per cent on March 1, 1918, without opposition from the consumer and again increased September 1, 1924. As I see it, the principal difficulty with the "ready to serve" system is the lack of understanding on the part of the consumers. Of course many of them are foreigners who do not understand English to any extent, but even many of those who do seem unable to grasp the idea.

I noticed in the September 1, 1926, edition of the "Water Works Engineering," page 1121, an article by Caleb Mills Saville, the

Manager and Chief Engineer of the Board of Water Commissioners of Hartford, Connecticut, in which he speaks of "the odium of the hated service charge" and continues that Hartford adopted the minimum charge system "which is satisfactory to everybody." From this I take it that Hartford people do not favor the ready to serve rate system, although it seems to have the approval of divers commissions, rate experts and others who understand its principle.

As I have battled with these matters for a number of years I would like very much to hear what other members of the Association have found out about such matters.

METER OVER-REGISTRATION COMPLAINTS

F. B. Beech:[4] Shakespeare must have had a disgruntled water consumer in mind when he wrote "More water glideth by the mill than wots the miller of" and having no water meter he did not have to concern himself with quantity. The water works man of to-day is well aware of the passage of this unheeded water and the task of imparting his knowledge to an incredulous and often times indignant customer, before a large and unsympathetic audience (waiting to pay bills), requires a great deal of tact as well as all the known virtues. In other words, he is sowing his seed on unbroken ground in a thunder storm. The ground is cultivated by some water companies by enclosing "water leak pamphlets" with all water bills and if these pamphlets were properly studied and understood, very few complaints would be received. The great trouble with pamphlets is that too many are received by the individual. He receives one with his gas bill, his electric light bill, his telephone bill and often with his milk, ice and bread bills. Personally I read none, excepting the water pamphlet, which is studied to pick out flaws. A full knowledge of the facts and personal contact, coupled with excellent judgment, are necessary to satisfy complainants. A useful means of demonstrating quantity is a coin with $\frac{1}{32}$-, $\frac{1}{16}$- and $\frac{1}{8}$-inch holes drilled though it and giving, under each opening, the gallons of water wasted in 24 hours at 40-pound pressure amounting to about 180, 960 and 3800 gallons, respectively. If it were not for the fact that 90 per cent of complaints are due to leaking toilets, it might be well to install three taps in a conspicuous place adjacent to where bills are paid, each tap placarded and running to waste at the aforementioned rate.

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[4] Superintendent, Ohio Valley Water Company, McKees Rocks, Pa.

Usually sympathetic explanations are best, but occasionally the patient needs a major operation. For example, the Water Company received the following letter:

Gentlemen:

The enclosed 2 bills are extremely high. Could you not please investigate and reduce same? You can see for yourself that such large amounts are grossly exorbitant.

The reply was:

Dear Sir:

In reply to your complaint of exorbitant water bills, we find that each quarter you complain of high bills, but your complaint is not entered until bills are at least two months overdue and shut-off notice has been served upon you.

There is no mystery about the high bills and we have frequently pointed out the cause. The fault lies in poor piping and water fixtures, together with careless tenants, factors over which the Water Company has no control.

Instead of shutting off water to-day (as per our notice) we are extending the time until Wednesday, September 15th and trust we shall receive your remittance before that date.

The complaint having been made, the bill is lifted and marked "to be re-read." An inspector takes the bill, re-reads meter, entering date and reading on the bill, at the same time inspecting meter especially as to whether or not the register bands (straight reading meter) are shrunk by hot water or fire, also listening on water line for running water. The rate per day at which meter is running can then be determined up to time complained of and also from that time to the date of re-reading of meter. These facts are aids to arriving at a conclusion. If customer has a just complaint, a corrected bill is rendered. If the account is correct, the original bill is returned to customer with the notation in red. "Inspected and found correct."

We check for leaks by listening on water line and observing meter while all fixtures are closed and by making sure the toilet is not leaking at overflow, the discharge, or by reason of cracked overflow pipe. We also make certain that there is no intermittant leakage on account of flush ball not seating properly or by the float ball scraping against the side of tank.

As a final resort, consumer is referred to the following printed rule:

Should any consumer of the Water Company at any time doubt the correctness of the meter measuring his service, he may, on application to the Water

Company and the deposit of two dollars to defray the cost, have said meter tested, and should said test show the meter in question to be correct within 3 per cent he shall bear the cost of said test. On the other hand, should the test show the meter to be registering incorrectly beyond 3 per cent of the accurate amount, said deposit of two dollars shall be refunded and the account adjusted accordingly and the entire cost of the test shall be borne by the Water Company.

EXPERIENCES WITH LEADITE

Charles L. Fox:[5] Twenty years' experience with leadite has convinced the Pennsylvania Water Company that it is a very satisfactory jointing material and for that reason it is using no other material in the jointing of cast iron water pipe. When planning to use leadite for the first time, instruction should be sought in its handling, melting and pouring before attempting to make any joints with it. Otherwise the work will be a failure. A couple of hours of instruction from a competent instructor will prepare any person to make successful leadite joints.

The continued use of leadite will soon prove that it is an economical jointing material. It reduces the time required to lay pipe, saves in labor by eliminating large bell holes and the caulking of joints and reduces the waste of water by cutting down the leakage at joints.

Experiences gained recently while laying 6 miles of 20 inch pipe tend to show that joints made with leadite can be made nearly water tight with a little added care and attention. To obtain water tight joints the first suggestion would be to remove as much as possible of the protective coating from the outside of the spigot end and the inside of the bell of the pipe. It was observed while laying this 20-inch pipe during the winter that very excellent results were obtained in reducing leakage at joints. The pipe had been exposed to the cold and was full of frost so that before commencing to lay, it was necessary to heat the bell and spigot end of the pipe, which was done either with a plumber's blow torch or a bit of waste saturated with gasoline, then lighted and held to the part of the pipe it was necessary to heat. In doing this the protective coating was removed. After the pipe had been laid and the joints poured the line was tested in sections and it was surprising to find the uniformly tight joints that were produced under these conditions, as it had been anticipated that the number of leaking points due to the weather conditions and frost in the pipes would be greater than under the ideal conditions of summer.

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[5] Assistant Superintendent, Pennsylvania Water Company, Wilkinsburg, Pa.

Leadite joints have been found to leak more at the top where the

TABLE 1

Data of test of 25,462 feet of 20-inch cast iron bell and spigot pipe—1926

DATE	TIME	ELAPSED TIME		METER READING	DIFFERENCE BETWEEN READINGS*	DAILY DIFFERENCE 24 HOURS	GALLONS PER HOUR PER 100 FEET	GALLONS PER DAY PER MILE	GALLONS PER DAY PER INCH-MILE	GALLONS PER DAY (24 HOURS) PER FOOT OF JOINT
	a. m.	*hours*	*minutes*	*cubic feet*	*cubic feet*	*cubic feet*				
July 7	11:16	26	37	85,683	510	459.84	0.563	713.82	35.7	0.312
July 6	8:39	24	33	85,167	513	501.36	0.614	778.27	39.0	0.334
July 5	8:06	21	51	84,644	453	497.52	0.609	758.81	38.7	0.330
July 4	10:15	25	50	84,185	540	525.84	0.644	816.27	40.9	0.355
July 3	8:25	23	49	83,633	496	508.80	0.623	789.82	39.5	0.343
July 2	8:36	24	14	83,128	530	524.88	0.643	814.78	40.8	0.354
July 1	8:22	23	47	82,588	526	530.88	0.650	824.10	41.2	0.358
June 30	8:35	23	35	82,052	536	545.52	0.668	846.82	42.4	0.368
June 29	8:50	24	22	81,507	556	547.44	0.671	849.80	42.5	0.369
June 28	8:28	22	21	80,945	522	560.40	0.686	868.12	43.5	0.377
June 27	10:07	25	34	80,415	603	565.92	0.693	878.49	44.0	0.382
June 26	8:33	24	02	79,806	565	564.24	0.682	864.48	43.8	0.376
June 25	8:31	24	15	79,235	577	570.96	0.699	886.31	44.8	0.385
June 24	8:16	23	17	78,649	559	576.24	0.706	894.51	44.8	0.388
June 23	8:59	24	25	78,084	513	504.24	0.618	782.74	39.2	0.340
June 22	8:34	23	54	77,568	717	720.00	0.882	1,117.67	55.9	0.486
June 21	8:40	24	40	76,844	657	639.12	0.783	992.12	49.7	0.431
June 20	8:00	23	18	76,181	626	644.88	0.790	1,001.06	51.1	0.435
June 19	8:42	24	10	75,543	663	658.32	0.806	1,021.92	51.2	0.444
June 18	8:32	23	58	74,873	679	679.92	0.833	1,055.45	52.8	0.459
June 17	8:34	23	50	74,189	688	692.88	0.849	1,075.57	53.8	0.467
June 16	8:44	23	49	73,493	695	700.80	0.858	1,087.87	54.5	0.472
June 15	8:55	24	6	72,789	718	714.96	0.876	1,109.84	55.6	0.482
June 14	8:49	48	13	72,071	1,489	1,481.76	0.906	1,150.08	(57.6)	0.500
June 13	No reading taken								(57.6)	
June 12	8:36	23	42	70,582	751	760.56	0.932	1,180.63	59.1	0.513
June 11	8:54			69,831						

* Readings corrected by subtracting amount of water used through a service line on section tested.

pouring gate is attached than at the bottom or under side of the joint. The experience of last winter when the protective coating was removed would lead to the conclusion that the oil and tar of the coating floats to the top of the joint and mixes with the leadite, leaving it porous at this point.

Another lesson that was learned was that pipe laid and jointed during the hot summer weather should be tested and backfilled as soon as possible. Pipe that lies in the open trench for any length of time in summer seems to creep, due to the heating of the sun, with the result that the usual good adhesion of the leadite to the metal of the pipe is destroyed and numerous small leaks appear around the pipe, i.e., between the leadite and surface of the pipe. By testing and backfilling promptly the number of defective joints can be reduced and leakage reduced to a minimum.

Experience has shown that leakage through leadite joints tends to decrease with age. Tests of the 20-inch line recently laid show this to be a fact.

Table 1 shows the test of 25,462 lineal feet, or 4.82 miles of 20-inch pipe for a period of 26 days, June 11 to July 7, 1926, with the pressure ranging from 70 to a maximum of 225 pounds per square inch, depending upon the topography of the country through which the line was laid. It will be noticed that the daily difference in leakage dropped steadily from 760.65 cubic feet for the first 24 hours to 459.84 cubic feet for the last 24 hours of the test, or a decrease of about 39.5 per cent. The valves at both ends of the stretch of pipe to be tested were closed and water was supplied to the line at the upper end through a $\frac{5}{8}$ inch meter calibrated to register on a small flow of water. In this manner the pipe was always under a constant head of water and readings were made about the same time each day during the test.

MUNICIPAL FIRE HYDRANT RENTAL

W. C. Hawley:[6] A charge for public fire protection based upon an annual rate per hydrant is neither a measure of the cost of the service to the water utility nor of its value to the public. It usually results in the setting of a minimum number of hydrants with consequent poor quality of fire protection service so far as the public is concerned and a return to the water utility of a revenue far below the cost of the service rendered. As a result, a considerable part of the cost of the service must be added to the domestic and industrial rates for water and thus the consumer who uses large quantities of water pays more than his fair share of the cost of fire protection service, while another consumer, whose property may be a serious fire hazard, will, because he uses a small amount of water, pay far less than his fair share.

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[6] Chief Engineer and General Superintendent, Pennsylvania Water Company, Wilkinsburg, Pa.

In addition to an annual rate per mile of distribution system for public fire protection service, there should be a small annual rate per fire hydrant, sufficient to cover interest, depreciation taxes, and maintenance on the hydrant itself. This of course is small compared with the ordinary rate per fire hydrant, ranging from eight to twelve dollars. The result is that the municipality can order additional fire hydrants at a comparatively small increase in the annual bill for public fire protection. It has been the writer's experience that where the rates have been changed from the rate per hydrant method of charging to the rate per mile method, the number of fire hydrants has been increased by from 30 to more than 100 per cent. The results so far as the public is concerned are better fire protection and correspondingly lower fire insurance rates and a more equitable distribution of the cost of furnishing fire protection. The water utility generally receives an increase in revenue and is less liable to criticism for furnishing poor fire protection service. In this connection it should be kept in mind that but few of the Public Service Commissions have been willing to fix public fire protection rates which even approximate the actual cost of the service.

Another important feature of the rate per mile charge is that it assists in securing extensions of distribution pipe, where such extensions are necessary to reach prospective consumers. There has been some objection to charging for fire protection on a pipe on which a hydrant has not been set, but the water utility must make its investment in a pipe large enough to furnish fire protection when the pipe is laid and it is therefore reasonable that there should be revenue on this portion of the investment as well as on that required for domestic service. If this is not done, then either the rates paid by the domestic consumers must carry all of the investment in the extension or else the water utility suffers a loss until such time as the municipal authorities see fit to order a fire hydrant set. If there are domestic consumers, there must be buildings requiring fire protection, and, since fire protection is a public matter, an investment to furnish such service should be paid for by the public.

COMPLAINTS—HOW HANDLED

D. C. GROBBEL[7] **AND HAL SMITH:**[8] The majority of municipally owned utilities realize that the good will of the public is a particularly valuable asset, and every effort is made to secure and hold that good will. No public utility, especially one owned by the municipality, enjoys hearing complaints on the service rendered and, though every effort is made to render efficient and adequate service, yet there is bound to arise a certain amount of dissatisfaction. Fortunate, however, is the utility that has the confidence of the public and is able thus to obtain from their dissatisfied customers a statement of their grievances, for, surely, no amicable adjustment can be made unless the utility has a knowledge that a grievance exists. For this reason, the Detroit Department of Water Supply has adopted the policy of encouraging the reporting of complaints, whether real or imaginary. It is then up to the complaint bureau of the Department to convert as many complainants as possible into satisfied customers, and it must be conceded that the bureau in this regard is functioning splendidly.

There are many different kinds of complaints received by the Detroit Department, but this paper is only concerned with customer accounting as related to the billing for water consumed. A study of the persons making complaints on the score of their water bills shows that these people may be divided into four distinct classes.

First, the person who honestly thinks he has been incorrectly billed. These cases are promptly investigated, and if bill is found to be in error, a corrected bill is rendered, with an apology for causing the customer any inconvenience. If correctly rendered, they are informed as to the cause of increased consumption with the advice that, if the cause has not already been removed, to do so at once, in order to reduce future bills. This service is appreciated, and as the customer is willing and expects to pay for all water consumed, it is seldom that any one in this class remains dissatisfied. The

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[7] Assistant Superintendent (non-technical), Board of Water Commissioners, Detroit, Mich.

[8] Assistant Supervisor, Water Assessment Bureau, Board of Water Commissioners, Detroit, Mich.

Department finds that this class constitutes about fifty per cent of the total number of complaints.

Second, the excitable and thoughtless customer. He receives a bill somewhat higher than usual and without giving a thought to what might have caused it, rushes down to the office and demands an explanation. The Department is usually able to inform him at once of the cause of the increased consumption, by referring to reports made by meter readers. It is, however, not always an increased consumption, but often an additional charge made for meter repairs, or arrears added to current bill, both of which are plainly shown on bill, but which was not noticed by the customer. Usually the Department experiences but little difficulty in satisfying this class, as they have no desire to shirk a just bill. However, they are excitable and quick tempered, and it calls for a considerable amount of tact on the part of the complaint clerk to explain conditions without further arousing their anger. About thirty-five per cent of the complainants fall in this class.

A third class is that of the chronic kicker. This class complains simply for the sake of complaining and from force of habit. It is practically impossible to satisfy him, for the simple reason that he does not want to be satisfied. You cannot reason with him because he will not listen to reason. He simply states that the bill is wrong and won't pay it. He does not want an investigation made. He knows how much water he used and does not care what the meter reads. He says we are just as bad as the Gas Company, the Electric Company and the Telephone Company. He certainly should know because he makes the rounds regularly to all the utilities, always registering a complaint before paying a bill, whether the bill be large or small. If the bill is smaller than usual, he brings it in to show that he was over-charged on previous bills. The fact that the building was vacant most of the period means nothing to him. This is the class that tests the mettle of any complaint clerk. If the clerk cannot satisfy him, he must come as close to it as possible and get him out of the office before he becomes too noisy. Arguments of this kind have a bad effect on other customers who might also be in the office to question a bill, and it is quite possible that the argument might create another chronic complainer. The Department finds about ten per cent of the complaining customers come in this class.

The remaining five per cent is composed of those customers who deliberately make an effort to get something for nothing. The person in this class receives a high bill and knows right well the reason for the increased consumption, but he is willing to make an affidavit that he knows there have been no leaks, wastage or increased consumption, and will invent an elaborate story to prove that the amount of water billed could not possibly have been consumed. He welcomes an investigation,—sure, certainly,—because he has already removed the cause of the high consumption. In this case, the complaint is given to one of the Department's investigators, who finds that the reading is correct, the meter in perfect order and showing no leak, and the consumption back to normal. However, a further investigation reveals a new toilet showing signs of being recently installed, or flush ball or washers replaced.

With this information at hand the complaint clerk is well armed, in fact, too well armed, for he has weapons that he cannot use. To prove that the complainant is a liar accomplishes nothing, it would simply cause the very thing that the Department is trying to avoid, namely, friction. So the tactful complaint clerk simply states that the reading was verified, the meter found to be in good order, and no leaks at present; that the increased consumption was apparently caused by a faulty toilet which had been recently repaired. He will probably think that the Department knows more about the facts than stated by the complaint clerk, but nevertheless it gives him a chance to save his face, and he quickly grasps the chance by blaming some tenant or employe for not informing him of the condition of the plumbing fixtures.

To properly handle complaints, as above classified, it is apparent that it is necessary to have a well trained and organized complaint bureau, whether it consist of one person or of a number of persons. In Detroit the complaint clerks are men who are familar with the construction, operation, and reading of meters, who have a fair knowledge of accounting and are especially equipped with an inexhaustible supply of tact, consideration and forbearance, ready at all times for instant use.

The complaint organization is a sub bureau, under the Assessment Bureau, which is that bureau of the Department which determines the amount of water to be charged against each consumer and such other duties as are naturally allied. Itemized, these duties are as follows:

Reading of meters.

Testing and reporting meters out of order.

Delivering bills.

Reporting new buildings ready for meter.

Reporting those that should be ready but are not. In brief, making a complete quarterly survey of the city to see that all water consumed is accounted for.

Estimating consumptions where no reading can be obtained.

Receiving and investigating complaints of water bills and performing such clerical work as necessary in carrying out the work of this Bureau.

It is therefore seen that the complaint bureau is working in close coöperation with that force that determines the amount of the water bills, and makes the reader's and investigator's reports readily accessible, and special information easily and quickly obtainable.

The Complaint Bureau proper consists of but two clerks; investigations are made by the two Meter Reader Foremen and a Chief Inspector. All correspondence is handled by the Supervisor of the Assessment Bureau or his Assistant.

The routine method of handling complaints is as follows:

Immediately upon receipt of complaint the account is checked for clerical error. If no mistake is found here, the meter reader's report is consulted to see if he has explained the high consumption. Usually he has, as one of the duties of a reader is to check any over or under consumption. With this information, the complaint clerk is able in most cases to convince the complainant that he is correctly billed. If he fails in this, he informs the customer that he will send out an investigator who will check the reading, examine the meter and if possible locate the cause of the increased consumption, and that he may obtain a report of the investigation by calling or phoning the office any time after the following day, or if he prefers he will be notified by phone or mail. A complaint form is then filled out giving such information as will be of help to the investigator.

The Department is not only willing, but is most anxious to spend any reasonable amount of time and money to secure the facts, in order that the consumer may be convinced that the Department has rendered a correct bill. It has been said that the large consumer, because of his superior maintenance organization, does not generally object to the bills of the Department, as rendered, but to illustrate the policy of the Detroit Department, an investigation of the water consumption of the largest social club in the city of Detroit was undertaken. This club has been approximating a consumption valued at $1300.00 per quarter. For the quarter from January to May, the value of the consumption increased to $1800.00. Naturally, the manager of the club wanted to be shown; therefore immediate steps were taken to investigate the complaint. Meter reader reports were consulted and it was found that a Meter Reader had OK'd the reading. Further, that two days after the regular reading, a check reading was taken and found all right. The Department's Pitometer Engineer was sent on the job and spent several hours with a crew of men in the building, but could find no leaks. However, he found that the Club had indulged in a large number of swimming meets, both for men and women, during the quarter in question. Being of a sportive mind he discussed the swimming meets with the Maintenance Engineer and it was discovered that the pool had to be emptied three or four times for repairs and cleaning, and further that the swimming meets for the ladies took place in the afternoon and for the men at night and that the temperature of the pool for the men was 70 degrees Fahrenheit, and for the ladies, 80 degrees, necessitating a frequent partial emptying of the pool to attain the proper degree of temperature. A report was made to the club which apparently was not satisfactory. Again the pitometer crew made a survey and checked the meter against pitometer readings. In this check it was found that the meter, a six inch one, was registering approximately two per cent under the pitometer registration. On submitting this information, the manager of the club demanded a further check and again the pitometer crew made an inspection and survey of every water fixture and water line in the building. The result of this survey showed that there was considerable waste in the club's refrigerating plant. The findings of the pitometer survey were sent to the club manager and yet the club management was not satisfied. The survey and inspection cost the Department approximately $100.00. This is a case out of the ordinary, for usually the findings of the inspection made for waste or undue consumption are conclusive and there is no question on the part of the consumer, who usually follows the suggestion made by stopping the waste or repairing the leaking equipment.

Where, like the club mentioned above, the complaint bureau is unable to satisfy the complainant, the complainant may appeal to the Board of Water Commissioners. The Board of Water Commissioners, naturally, is unable to handle all the details of a department serving the public at the present time through over 220,000 meters, and the Board therefore has constituted an "Adjustment Committee," who sit as a Board of Review on the petition of the complainant and the findings of the complaint bureau. This Adjustment Committee is made up of the General Manager, Engineer of Water System, the Assistant Superintendent and the Superintendent of the Personnel Bureau. All the facts and findings in the case are submitted to this Committee in writing and the Committee makes the decision for or against the petitioner. The Committee further submit their decisions to the Board for approval.

This is final as far as the Department of Water Supply is concerned. Naturally the petitioner still can have recourse to the courts and to the Mayor and Council of the City, but since the institution of this Adjustment Committee as a final court of facts, no complaints against the bills of the Department have been carried to the Mayor, the Council or the Courts.

The Department has endeavored by all possible means to reduce the number of complaints and forestall many of them, first, by anticipation, that is, by notifying the consumer of an unusually high consumption immediately upon discovery by the reader, also informing him of the cause, where possible, and advising him to take immediate steps to remedy the trouble as it has already caused a considerable increase to his bill, and that a second high bill can be avoided by giving the matter his prompt attention. Second, a continual publicity campaign stressing the fact that water leaks or wastage are a real but unnecessary expense. Third, a firm policy of adjustments, making it clear to the consumer that it is useless to register a complaint where water is known to have passed through the meter, whether for useful consumption or through careless waste.

The Detroit Department considers its complaint bureau one of the most valuable adjuncts of the Department, and the writers in concluding the paper desire to credit the Supervisor of the Assessment Bureau for much of its success.

CARRYING CAPACITY OF PIPE

F. F. Longley:[9] The writer would like to contribute to this discussion some records of hydraulic studies on reinforced concrete pipe lines built by the Lock Joint Pipe Company.

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[9] Engineer, Lock Joint Pipe Co., Ampere, N. J.

TABLE 2

Values of "C" in lock joint pipe lines—Summary of results of recent observations on the hydraulics of several long sections of two lock joint reinforced concrete pipe lines

	TULSA, OKLAHOMA—SPAVINAW WATER SUPPLY LINE (NEW)			NORFOLK, VIRGINIA—LAKE PRINCE WATER SUPPLY LINE (3 YEARS OLD)	
	Section 1	Section 2	Section 3	Section 1	Section 2
Diameter of pipe, inches	60.0	60.0	54.0	36.0	36.0
Length of line under test, miles	6.6	15.3	4.0	2.17	2.47
Mean Velocity, feet per second	2.25	2.25	2.63	2.89	2.90
Rate of discharge, millions of gallons per day	28.596	28.550	27.029	13.20	13.23
Slope of hydraulic gradient, feet per 1000	0.2052	0.1880	0.2851	0.658	0.623
Value of "C" (Williams-Hazen)	145.4	152.4	152.1	138.0	142.0
Value of "C" (Scobey)	0.386	0.402	0.409	0.380	0.392

TABLE 3

Values of "C" in lock joint pipe lines: Summary of results of observations on hydraulics of 54-inch pipe line (Conduit No. 10)—Denver, Colo.

First section had been in service about 5 years; second section had just been put in service.

	TEST AT VELOCITY 3.50 FEET PER SECOND			TEST AT VELOCITY 2.58 FEET PER SECOND		
	First section	Second section	Combined	First section	Second section	Combined
Diameter of pipe, inches	54.0	54.0	54.0	54.0	54.0	54.0
Length of the line under test in miles	3.52	2.63	7.25	3.52	2.63	7.25
Mean velocity, feet per second	3 50	3.50	3.50	2.58	2.58	2.58
Rate of discharge, millions of gallons per day	35.96	35.96	35.96	26.46	26.46	26.46
Slope of hydraulic gradient, foot per 1000	0.5041	0.5330	0.5233	0.2673	0.3317	0.2994
Value of "C" (Williams-Hazen)	148.0	145.0	146.0	154.0	138.0	146.0
Value of "C" (Scobey)	0.407	0.396	0.400	0.412	0.370	0.390

Tulsa, Okla., has a water supply conduit built of lock joint reinforced concrete pipe 60 inches and 54 inches in diameter and with a total length of about 52 miles. Tests were made on the carrying capacity of this line shortly after it was put in service during the year 1924.

Norfolk, Va., has a 36 inch water supply line running in from Lake Prince. Part of this is of lock joint reinforced concrete pipe. Some studies for the determination of its carrying capacity were made in 1924.

The City of Denver, Colo., has several lock joint pipe lines among which is one 54 inches in diameter and nearly 10 miles long. About half of this line was built in 1920 and the other half completed and put in service in 1924. The carrying capacity of this line was determined by some carefully conducted studies early in 1925.

The Tulsa and Denver measurements were made by Fred C. Scobey of the Bureau of Public Roads, United States Department of Agriculture, whose pamphlet on "The flow of water in concrete pipe," (Bulletin 852, U. S. Department of Agriculture) summarizes a large volume of information on this subject. The Norfolk measurements were made by Walter Taylor, Commissioner of Public Works of Norfolk, collaborating with Dabney R. Maury.

The results of these studies have all been reported in some detail in the columns of the Engineering New Record within the past two years, and are given in summarized form in tables 2 and 3.

It will be observed at once that the values of "C" (Williams-Hazen) observed on these lines are remarkably high, the several figures ranging from a minimum of 138 to a maximum of 154.

The measurements on the Tulsa line and also on the second section of the Denver line were made when the pipe had been in service only a short time. The measurements on the Norfolk line were made when the line was about three years old, and on the first section of the Denver line when it was about five years old. An examination of the figures shows unmistakably that remarkably high coefficients were found in the pipe lines that had been in service three years and five years, without any evidence whatever of surface deterioration or falling off of carrying capacity as compared with the measurements made on new pipe.

REHABILITATION OF THE RACINE WATER WORKS[1]

By Donald H. Maxwell[2]

The water works at Racine, Wis., has been municipally owned since May 1, 1919. When taken over the plant was underbuilt, partly from the fact that several years of litigation preceding transfer had discouraged capital expenditures that could be deferred.

At the time of transfer, the investment in the plant, based on valuation at prewar prices, was equivalent to about $21 per capita. In contrast, the average per capita cost of water works plants in cities of over thirty thousand population was $32 per capita, as shown by the 1910 United States Census Statistics. This comparison confirms in a rough way the fact that the plant when purchased was considerably underbuilt.

PRINCIPAL DEFICIENCIES

The most important deficiencies were in intake and pumping capacity. It might also be added that the plant did not include filtration, although this development had been under consideration for a number of years during company ownership.

INTAKE CAPACITY

When the plant was taken over, the neck of the bottle was the intake. This consisted originally of a 24-inch cast-iron pipe extending 7600 feet to a submerged timber crib in about 40 feet of water and at the shore end turning down into a suction well.

The main pumps are set at about elevation +12, permitting them to develop a supply of approximately 5 million gallons per day. In 1899, the Company added a booster pump, which increased the intake yield to about 9 million gallons per day.

This booster installation consists of a screw pump mounted in a vertical shaft and supplied through a 4-foot tunnel by a siphon by-pass connection from the intake line. This installation develops very nearly the maximum capacity of the intake.

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[1] Presented before the Illinois Section meeting, March 24, 1926.

[2] Principal Assistant Engineer, Alvord, Burdick & Howson, Chicago, Ill.

By 1919 the screw pump had come into daily use, and the need of a reserve unit to boost to the suction well was urgent. This improvement was carried out in 1920.

NEW BOOSTER PUMP

The new booster installation consists of a slow-speed, direct-connected engine driven centrifugal pump, set at elevation −8, and taking suction from the tunnel through an 18-inch well casing driven through the brick roof of the tunnel. The pump also has a suction connection direct to the 24-inch intake line, permitting the tunnel to be by-passed for cleaning, and discharges through the intake to the suction well. This pump develops a slightly greater supply from the intake than it is possible to secure with the screw pump, and, in fact, develops the maximum capacity of the intake as a siphon, or a rate of about 9.5 million gallons per day.

This booster equipment enables the plant to supply a city of 70,000 through a long 24-inch intake, and in connection with storage now provided or under construction, is expected to make the present intake sufficient for the city's requirements for several years to come.

GENERAL REPORT

While this improvement was under way, at the request of the Water Board a general report was made in 1920, outlining a comprehensive program of betterments.

NEW SITE

Study of the water works lot in connection with the required improvements made it evident that a better site was urgently needed. The existing lot is from 100 to 125 feet wide by about 900 feet long, but badly divided by railroad switch tracks serving adjoining manufacturing property under conditions making it out of the question to eliminate them. These facts led the Board to secure the best available new site, a tract 260 feet wide by 1000 feet long and located two blocks north of the old plant. This lot is well situated and provides sufficient space for future expansion, so far as future requirements can be foreseen at this time.

COAGULATING BASIN

After careful study of the new site, a general design of the future plant was made and a program laid down for its construction in installments from time to time out of plant earnings, giving preference to the more urgent improvements. This program contemplated building the new intake first, but shortage of funds and the prevailing high price of cast iron pipe led finally to a decision to build instead the coagulation basin of the proposed filter plant, the idea being that this would provide sufficient storage, using it as a reservoir, to tide the city over the intake deficiency for a few years and have the advantage over a new intake at that time of considerably less expenditure and some improvement in the water supply, through sedimentation. The coagulating basin was purposely built somewhat large to provide adequate reserve water supply, and has a total sedimentation period of about six and one-half hours based on the present average daily pumpage.

The basin was completed in 1925 and provided with temporary connections to permit its use as a reservoir. It is connected with the old site by two mains, one for supply and one for outlet, one of which may in the future be utilized as a high pressure discharge main from the new station, and the other as an extension of the old intake to the new station suction well.

FILTER PLANT

In the meantime, local conditions developed which led the Board again to postpone the proposed new intake, in favor of completion immediately of the filter plant. This plant is now under construction and is to have a rated capacity of 12 million gallons and total filtered water storage of 3 million gallons. This increased storage will make the existing 24-inch intake sufficient for a few years more, or until such time as the Water Department can accumulate a sufficient construction fund to finance the proposed new intake out of earnings, in accordance with the policy adopted by the Board.

FUTURE IMPROVEMENTS

After the proposed intake and new suction well have been provided at the new site, the next step will be to build a complete new pumping station adjoining the filter plant. The new plant is laid out to lend itself to orderly expansion from time to time to meet the future needs of the city and probably even its ultimate requirements, so far as they can reasonably be anticipated at this time.

MANAGEMENT

The Racine Water Department is controlled by a Board of Water Commissioners, and is under the direct management of F. M. McElroy, who was also Superintendent of the plant under private ownership.

PROGRESS REPORT OF COMMITTEE ON STANDARD FORM OF CONTRACT[1]

The Committee on Standard Form of Contract has been inactive during the past year. This policy was followed in order to learn by experience how the public received the standard contract forms which the Committee helped to prepare as an affiliate in the Joint Conference on Standard Construction Contracts. These forms will be found on pages 715–727 of the "Manual of American Water Works Practice."

The documents relating to engineering contracts are printed officially for the Joint Conference by the Associated General Contractors of America. They are on 9- by 12-inch sheets readily bound with the typewritten specifications, notice to bidders and other documents making up a complete set of contract papers. About a thousand of these documents have been sent out as a result of requests received at the office of the Associated General Contractors in the Munsey Building, Washington. The standard engineering construction documents have also been published unofficially in the Proceedings of the American Society of Civil Engineers as well as in our own Manual, and probably some use has been made of them by copying from these sources. They have not yet been out long enough to enable one to judge what their future usefulness will be.

Your Committee is desirous of learning the experience of our members in using, or attempting to use, these documents, which represent a great deal of labor and study by engineers representing all branches of the civil engineering profession, delegates of the American Institute of Architects, general contractors, and lawyers specializing in contract law.

The American Society of Municipal Improvements has been considering for some time this subject of standard construction contracts, and one of its committees will present at the annual meeting in the coming Autumn a set of documents much like those of the Joint

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[1] Presented before the Buffalo Convention, June 8, 1926.

Conference, except that references to arbitration are omitted as mentioned in the footnote on page 715 of our Manual.

Your Committee asks the Association to receive this report and to continue the Committee.

Respectfully submitted,
J. Waldo Smith, *Chairman,*
Committee on Standard Form of Contract.

REPORT OF COMMITTEE NO. 1 ON STANDARD METHODS OF WATER ANALYSIS[1]

Your Committee No. 1, on Standard Methods of Water Analysis, begs leave to submit the following report for the year 1925–1926:

This year has seen the appearance of the Sixth Edition of the Standard Methods for the Examination of Water and Sewage prepared jointly by the Committees of the American Public Health Association and the American Water Works Association. This represents the first edition under the coöperative arrangement. The material for this edition was submitted and approved at the Convention in Louisville in 1925.

The work of your Committee No. 1 during the current year has consisted almost entirely of research work as detailed herewith.

The Composition of Billiant Green Lactose Peptone Bile, H. G. Dunham, Referee

Mr. Dunham and Dr. Levine, with the assistance of Dr. John F. Norton and Dr. S. A. Koser, are working on a comprehensive program to improve the brilliant green lactose bile medium. The points which are being given careful, scientific consideration are:

The concentration of the bile
The concentration of the brilliant green
The hydrogen ion concentration of the completed medium

Work has been carried out at Iowa State College at Ames, under Dr. Levine, at the plant of the Digestive Ferments Company, at Detroit, under Mr. Dunham, at the University of Chicago, under Dr. Norton, and at the University of Illinois, under Dr. Koser. The technical details of Dr. Levine's results so far are included later, under Dr. Levine's name, as they were submitted by him. The assistance of the Digestive Ferments Company in the study of this medium is particularly appreciated, as they have contributed materially in a financial way to the support of the work.

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[1] Presented before the Buffalo Convention, June 11, 1926. Committee No. 1 consists of Jack J. Hinman, Jr., Chairman, R. C. Bardwell, John R. Baylis, L. I. Birdsall, Julius W. Bugbee, A. M. Buswell, H. G. Dunham, Norman J. Howard, Harry E. Jordan, Wilfred F. Langlier, Max Levine, MacHarvey McCrady, Dale L. Maffitt, F. W. Mohlman and E. C. Trax.

The work carried on by Dr. Norton includes the use of two strains of Bact. coli giving the typical reactions of fecal Bact. coli. His results, representing averages of seven series of counts with each organism, indicate that lactose peptone bile containing one, two or five per cent bile causes a slight inhibition of these strains as compared with peptone water. In the 2 per cent bile medium containing added brilliant green an appreciable inhibition was noted with both cultures in the 1:5000, 1:7500, 1:10,000 and 1:12,500 concentration of brilliant green. A lesser inhibition was noted in the 1:10,000 brilliant green 2 per cent bile medium with both cultures. Additional work is being planned using freshly isolated cultures.

The work of Dr. S. A. Koser has been to determine whether or not aerobic spore formers will grow in lactose peptone bile or brilliant green bile. Up to the present time, he has used 20 cultures of aerobic spore-forming lactose fermenters in 12 different media. One series of six included five different concentrations of brilliant green from 1:15,000 to 1:100,000 in 2 per cent lactose peptone bile with a control containing no brilliant green. The other series included five different concentrations of brilliant green from 1:10,000 to 1:30,000, in 5 per cent lactose peptone bile with a control containing no brilliant green. His tests were further controlled with standard lactose broth. The method was to inoculate each medium directly from young agar slants and incubate at 37°C.

Two types of cultures were used. Type I is apparently quite common in soil around Urbana and appears to be about the same as the cultures described by Hinman and Levine in Iowa, and by Norton in Chicago. Type II was rarely found in the Urbana locality.

All of the 15 cultures of Type I tested so far were inhibited by all bile media and brilliant green bile media (no visible growth and no gas production even after seven days at 37°C.). Apparently the inhibition is due to the bile since the control tubes of bile alone, both 2 and 5 per cent gave the same result. Standard lactose broth served as a further control. In this medium (standard lactose broth) the amount of gas produced by spore-formers varied from a bubble to 30 per cent; after forty-eight hours it was more pronounced and varied between 10 and 50 per cent.

Using five cultures of Type II, growth and gas production was apparent in all 12 bile and brilliant green bile media, sometimes only a bubble of gas after twenty-four hours, but usually pronounced after forty-eight hours. Very little, if any, inhibition was noted in comparison with the standard lactose broth.

Further work is planned using diluted water suspensions of the Type II cultures as an inoculum for the bile media. Plate counts on this type to compare their growth on bile media as compared with standard lactose broth are also planned.

The work in the laboratories at Detroit which was performed by Mr. H. W. Schoenlein has likewise been quite extensive. The growth of Bact. coli (fecal) was determined in lactose peptone bile media containing 1, 2, 3, 4 and 5 per cent bile. A control medium composed of the lactose peptone fraction of the bile medium was carried along. Tubes, in a 37°C. water bath, were inoculated with a measured amount of an active broth culture of two or more organisms. A mixture of cultures was used to minimize the effect of the individual. The test cultures were plated out on 1.5 per cent nutrient agar after five or six hours incubation at 37°C. in the water bath.

As a result of seven series of platings, using a mixture of two stock laboratory strains of fecal coli in 3 series, and a mixture of three fecal coli's isolated from rabbit, dog, and human feces respectively in four series, and employing two different oxgalls in the above mentioned media, the following conclusion is made: "In every case a decided stimulation was apparent in the bile media as compared with the control medium, which was the same as the bile medium except that no bile was present. It was also apparent from this series that from 1 to 3 per cent bile was the optimum concentration."

Further work is under way in studying the effect of the brilliant green and the effect of the hydrogen-ion concentration.

Conclusions. Until more cultures are used and reported by Dr. Norton, no conclusions can be drawn from his work. Plain lactose peptone bile and brilliant green bile media inhibit the growth of the more common lactose fermenting aerobic spore formers when inoculated in smaller quantities. The work here indicates that, as far as the cultures of fecal coli used are concerned, both laboratory stock and freshly isolated strains are stimulated by the presence of from 1 to 3 per cent bile in lactose peptone bile.

Non-Confirming Spore Formers and Their Significance in Water Examinations, Norman J. Howard, Referee

During the past year chief work has centered upon securing additional information on the subject, in correlating the ideas of observers on their local conditions and in securing and studying the characteristics of cultures. Correspondence with numerous observers has shown wide differences of opinion. In some cases such opinions are purely hypothetical and have no sound basis. It has been difficult to secure cultures. Of the cultures submitted some were contaminated, some were anaerobes and some only fermented lactose under difficult conditions of cultivation. Work is being continued. A brief résumé of observations recorded is as follows:

1. It is possible that troubles experienced in certain districts are not directly attributable to the presence of spore formers, but are caused by the combined presence of two distinct types of organisms neither of which are spore formers, but which produce gas in symbiosis.
2. In some districts the difficulty in confirming presumptive tubes is undoubtedly caused by spore formers.
3. Some specimens fermented brilliant green bile broth and lactose broth in twenty-four hours.
4. The use of dyes and bile broth cannot be depended upon to eliminate even their primary growth.
5. In some instances the use of bile in small quantities prevented the growth of spore formers.
6. There is no evidence, based upon cultures submitted, that the majority of non-confirming spore formers found in treated waters are B. welchii. They undoubtedly belong to a large group of unclassified spore forming bacteria.
7. The significance of the non-confirming spore forming bacteria in treated waters has not been demonstrated. Generally speaking, provided the colon group have been destroyed by purification processes, the spore forming group are unimportant.
8. In judging the quality of untreated water their presence may be of value in determining the probable source of pollution.
9. The pathogenicity of numerous strains is being determined and will be reported upon at a later date.

10. The presence of spore forming organisms in water has given in the past and doubtless will in the future give rise to grave inaccuracies unless steps are taken to provide a medium which will eliminate their growth in the primary test.

11. Work is being carried out along these lines, but on account of other studies overlapping, it is probable that much work is being unconsciously duplicated.

It is suggested that this study should not be confined to the spore forming group, but to include all non-confirming lactose fermenting organisms found in water.

Appreciation is expressed to Messrs. J. S. Gettrust, J. C. Weldon, Frank Raab, J. K. Hoskins, G. E. Willcomb, W. S. Mahlie, and R. E. Thompson for assistance to the referee in this study.

Use of Brilliant Green Bile and Media Containing Other Tri-Phenyl Methane Dyes as Secondary Fermentation Media in the Determination of the Bacteria Coli Group, Harry E. Jordan, Referee

Details of this work will be found described in part in the December, 1925, issue of The Journal. Additional summaries will be submitted at a later date.

The Use of Eosine Methylene Blue Agar and Modifications in the Confirmation of Organisms of the Colon Group, Max Levine, Referee

The work on the assigned subject is being deferred while Dr. Levine coöperates with Mr. Dunham, Dr. Norton, and Dr. Koser, on the composition of brilliant green bile. The status of the work on brilliant green bile as carried out in coöperation with Mr. Dunham, Dr. Norton, and Dr. Koser, is as follows:

The plan of the work was first to ascertain the optimum concentration of bile for stimulation of growth of Bact. coli, and then to ascertain the optimum concentration of brilliant green when employed with the previously determined optimum bile concentration.

Employing bile alone (that is, without brilliant green) a concentration of 2 per cent was practically always the best, in that there was always stimulation, although the degree of stimulation of growth varied with the different batches of bile employed.

With 5 per cent bile, the results were much more variable, one batch showing distinct inhibition, while another showed distinct stimulation in the growth of a mixture of strains of Bact. coli. It was felt that the differences observed might be explained in part at least by the differences in reaction.

Mr. Dunham prepared three batches of 5 per cent bile media with reaction of pH 6.0, 7.3 and 7.8. The generation times for a mixture of 5 strains of Bact. coli in these bile media were 30.9, 26.2 and 25.8 minutes as compared with 30.0, 30.1 and 35.0 for lactose broth media of corresponding reactions. It will be observed that in the alkaline reaction (pH 7.8) the 5 per cent bile was distinctly stimulating whereas in the acid reaction pH 6.0 it was slightly inhibitory.

It is, therefore, evident that in all future work on this project, it will be necessary to control the H-ion concentration in order to have comparable results.

The optimum concentration of brilliant green is a function of the concentration of bile. In 2 per cent bile, best results were obtained with 1:100,000 brilliant green and with 5 per cent bile 1:25,000 to 1:30,000 brilliant green appeared best. In general 1:30,000 brilliant green had about the same stimulating effects on growth of Bact. coli. Higher concentrations of the dye exerted a slight to distinct inhibition.

The experimental work upon which this report is based was done by Mr. H. W. Coles as a thesis for his master's degree in bacteriology.

The Use of Brilliant Green Bile as a Primary Medium in the Detection of Organisms of the Colon Group, MacHarvey McCrady, Referee

Work on the above assignment was confined, during the past year, to preparation of a report, for publication in THE JOURNAL, on the results obtained during the intensive study of the two preceding years. In collaboration with Mr. H. G. Dunham and Mr. H. E. Jordan, who were interested in particular phases of the general subject, a report was prepared and published in THE JOURNAL, December, 1925.

Considerable interest appears to have been aroused by this work of the past three years, as several requests for information regarding details of the work and several offers of contributions to the study have been received from laboratories not represented in the Association.

During the past year further study was given the medium by Mr. C. J. Lauter of the Washington Filtration Plant. A preliminary comparison of results obtained with the medium and with standard broth was forwarded by Dr. A. H. Straus of the Bacteriological Laboratories of the Virginia State Board of Health, which indicated that the brilliant green bile medium might clear up certain anomalous results yielded by the standard broth when employed on some open swimming pool waters. Dr. Straus is carrying this work further.

To satisfy the demand of those laboratories which have found the medium of particular value in their work, a dehydrated brilliant green lactose peptone bile medium has been prepared by Mr. Dunham, which has been tested and approved by Dr. F. E. Hale (in whose laboratories the original medium was prepared), and has been placed on the market by the Digestive Ferments Company of Detroit Mich.

The first phase of the work on the above assignment is now considered concluded. A large mass of data has been gathered on the value of this medium, and it is believed that the data are of particular interest in that they are based upon a medium made up of standard ingredients; each ingredient was given special consideration, and, where necessary, the specified ingredient was furnished the various associates, so that all might work with the same materials. It is believed that a few individual reports, however complete, could never have permitted the satisfactory judgment of the value of this medium obtained from consideration of this mass of data obtained from all sections of the country and from a great variety of waters.

These data have indicated very clearly that in some localities and with some waters the medium will give excellent results, but that it is not of general utility, as some waters have not yielded satisfactory results with the medium.

The next phase of this investigation must include a study of the possibility of improving this medium, which so nearly answers the requirements of a rapid, trustworthy presumptive medium, and the development of this phase is now in the hands of members of the Committee, as has been above indicated.

The Microscopic Examination of Water, W. F. Langlier, Referee

A Foerst continuous centrifuge, operating at 15,000 r.p.m. is now available to the Referee, and he is conducting tests on it in comparison with the net and the Sedgwick-Rafter methods, for the enumeration and estimation of the plankton organisms. A few trial comparisons have been made using all three methods. The work is slow and tedious and it is not always possible to secure suitable specimens of water. It is believed that the Foerst centrifuge marks a considerable advance over the older methods, but that it requires careful comparison with the older processes. It is hoped to have enough data accumulated by fall to permit certain conclusions.

The Mineral Analysis of Water, R. C. Bardwell, Referee

The progress in connection with mineral analysis of water for boiler purposes pertains largely to a thorough test of the recommended procedure published in THE JOURNAL, August, 1925, of the Association.

These methods have been given special consideration and tests in a large number of railway water laboratories with very satisfactory results. It is the recommendation of the Referee that the published procedure be adopted for standard practice in the examination of waters for railway boiler purposes and small steam supplies.

Mr. Bardwell, the referee, is also a member of Committee No. 19, under the chairmanship of Mr. S. T. Powell. The purpose of this arrangement is to insure the coöperation of both committees and to permit free interchange of available information.

The Determination of Turbidity and Coefficient of Settling, John R. Baylis, Referee

Work on a method for making accurate turbidity measurements of filtered water has been completed. A new turbidimeter has been designed. The new instrument is essentially the same as the one described in THE JOURNAL, July, 1924, page 824, but is of much neater design. Plans of the new turbidimeter and a method of procedure for making turbidity measurements with the instrument were published in Industrial and Engineering Chemistry, March, 1926, page 311.

There is yet the problem of trying to find a suitable method of procedure for measuring the floc turbidity, that is, coagulated matter passing a rapid sand filter bed. There is also need for a simple and reliable instrument to make turbidity measurements between

2 and 25. Some consideration will be given to this during the next year.

The Determination of Dissolved Oxygen, J. W. Bugbee, Referee

The original Winkler method is prescribed for use with waters containing less than 0.1 part per million of nitrite nitrogen, while the Rideal-Stewart modification is made the standard method for all waters containing more than 0.1 part nitrite nitrogen.

In paragraph 5 (Calculation of Results) mention is made of the fact that values in excess of 100 per cent saturation sometimes occur, and this condition is attributed to the presence of oxygen-forming plants. From the writer's own experience, and from reports received from other workers, it appears that this condition of supersaturation sometimes occurs under such circumstances that it cannot be explained by the reason given above. If other causes could be definitely proven, they, also, should be stated in paragraph 5 and the writer would suggest that committee members or other laboratory workers who may have met with such conditions be asked to report the facts in detail, with their theories or opinions as to the cause.

The fact that the modified Winkler method gives erroneous results, in the presence of iron salts, was brought out by Buswell and Gallaher, and, as they found that the error could not be corrected by applying a factor based on the amount of iron present, they advocated the use in such cases of the Levy method as modified by Letts and Blake. If this suggestion were to be followed, however, it would necessitate publishing the modified Levy method as an alternate to the Winkler method.

In Public Health Bulletin No. 151 (The Determination of Dissolved Oxygen by the Winkler Method) it is suggested by the author, E. J. Theriault, that the oxidizing effect of ferric chloride could be inhibited by the addition of sodium fluoride, and he proposed this as a modification of the Winkler method for liquors containing iron. Unfortunately, he did not use in his experiments as large amounts of iron as are sometimes found in actual field tests, and until further work is done along this line, the advisability of including his suggested modification is still somewhat in doubt. Undoubtedly the interference of iron should be mentioned in Standard Methods, and a method should be indicated for overcoming this interference, as soon as such method can be standardized. Until such time, it would appear that it would be of great assistance to a student of the problem to insert in the biliography of Section xxiv, the titles of the two articles mentioned above:

Buswell, A. M., and Gallaher, W. V. Determination of Dissolved Oxygen in the Presence of Iron Salts. Industrial and Engineering Chemistry, Vol. 15, No. 11, p. 1186 (1923).

Theriault, Emery J. The Determination of Dissolved Oxygen by the Winkler Method. Public Health Bulletin, No. 151 (1925).

The Determination of Free Chlorine, A. M. Buswell, Referee

The Referee and Professor Boruff, of Monmouth College, have concened themselves with the sensitivity of the ortho-tolidine method as compared with the starch iodide method for the determination of free chlorine. Both tests seem to be equally sensitive, giving a positive test for 0.005 part per million of excess chlorine in a 50 cc. Nessler tube at room temperature. The ortho-tolidine method is affected by iron when present as the chloride or nitrite above one part per million. Nitrites in low concentrations do not affect the test. Above one part per million they are objectionable. The hydrogen ion concentration is an important factor. The most sensitive concentration is that given by 2 cc. of concentrated hydrochloric acid in 50 cc. of water. The starch iodide test is more satisfactory for very low temperature determinations, but in general the ortho-tolidine test is preferred. The latter is much simpler than the other test in practice, since but one solution is required in addition to the standards.

At the request of the Chairman of the Committee, Dr. Buswell and Dr. Boruff have conducted an investigation into the preparation of ortho-tolidine solutions, requests having been received for information concerning residues remaining after attempts to dissolve the ortho-tolidine according to the method given in the Sixth Edition of Standard Methods. The conclusion reached is that ortho-tolidine is soluble in dilute hydrochloric acid but not in concentrated hydrochloric acid. This is undoubtedly due to the formation of ortho-tolidine hydrochloride, which, in turn, is soluble in water. It was noted that the impurities found in some commercial ortho-tolidine were not soluble in dilute hydrochloric acid but soluble in concentrated hydrochloric acid. Hence the action of dilute hydrochloric on the impure ortho-tolidine apparently dissolves very little of the impurities which may be filtered off. If concentrated hydrochloric acid instead of dilute hydrochloric acid is used in the preparation of the solution, which is then diluted to the desired strength, the dark colored impurity goes into solution and the ortho-tolidine is thrown out of solution. This is the reverse of what is desired.

The above situation results in one author reporting a residue soluble in water and insoluble in concentrated hydrochloric acid, while another author reports a residue insoluble in water but soluble in concentrated hydrochloric acid. The fact is they are dealing with different residues. The residue which is soluble in water is the ortho-tolidine or otho-tolidine hydrochloride, while the other residue, which is soluble in concentrated hydrochloric acid, is the impurity found in the material. The dark colored impurity is undesirable because when put into solution a colored liquid results which interfers later in the determination of free chlorine according to this method.

The Determination of Free Carbon Dioxide in Water, Dale L. Maffiti, Referee

In the search for a new method for the determination of free carbon dioxide in water an endeavor has been made to survey the available literature on the subject; actually to try experimentally in the laboratory some of the methods suggested; as well as to determine the practicability of new ideas which were conceived from time to time.

It has been found that a considerable amount of work has been done on the determination of carbon dioxide along three lines, namely: (1) Titration (2) Absorption (3) Volumetric Methods.

A method suggested by Dietl has been investigated. In this method the sample of water is added to an excess of standard sodium hydroxide solution. To increase the sodium ion concentration, so that the carbon dioxide will stay in solution, a reagent such as sodium citrate or tartrate is added, after which the mixture is titrated back with standard acid to find the amount of excess of sodium hydroxide. It was found that in this method practically all the difficulties found in other titration methods were encountered. Especially is this true where the water to be tested contains any salts that give an acid reaction in solution, such as iron and aluminum compounds and so forth. Also with the excess amount of sodium ions present the phenolphthalein indicator does not give a sharp end point.

J. Johnston points out that one of the disadvantages of such a method as described above is that varying amounts of carbonates, bicarbonates and carbon dioxide require different amounts of indicator to produce accurate results. Johnson also states that the only absolutely reliable methods are those determining the total base combined with carbonic acid and the total carbon dioxide present in solution and then subtracting to get accurate amount of free carbon dioxide.

The ordinary potash bulb absorption and also volumetric methods as suggested by Treadwell and Swanson and Hulett and others are not feasible for standard methods use, due to the outlay for complicated apparatus and the elaborate technique in handling same. These methods, however, are more accurate than the titration methods.

In a method lately suggested by E. M. Crowther and W. S. Martin, the sample is added to standard calcium hydroxide together with calcium chloride to precipitate the carbon dioxide as calcium carbonate, after which the mixture is titrated back with normal acid. This being a titration method would no doubt suffer from many of the disadvantages of the other titration methods. It too is but a variation of the barium hydroxide method given by Treadwell and Hall.

Thymol blue indicator was tried, but it does not seem to have an advantage over phenolphthalein, because it does not have a sharp end point under the experimental conditions.

An endeavor was made to adopt a method somewhat similar to that suggested by Swanson and Hulett. The scheme was to use mercury in a Muencke-Orsat apparatus, which was connected to the vessel containing the sample of water. The pressure over the sample was reduced by allowing the mercury to flow from measuring tube into the aspirator bottle. The carbon dioxide thus drawn from the sample was passed into the potassium hydroxide pipette of the apparatus and the amount of carbon dioxide noted by the reduction of pressure indicated on a manometer connected with the system. It was found, however, that the technique required was too elaborate for ordinary procedures and that it would therefore not be practical for inclusion in the standard methods.

The conclusions on the work thus far are as follows:

The present method as outlined in Standard Methods is the most practical for ordinary procedure, even though it is somewhat inaccurate. Where extremely accurate results are necessary as with some particular types of water the present method may be augmented by some more highly technical method such as the absorption method, thereby obtaining a factor of error to use in that case with the present procedure.

Some of the methods suggested have a slight advantage for particular waters, but it appears that absolutely accurate results can only be secured by comparatively complicated methods, and no method thus far suggested has especial advantage over the present method as outlined.

The Determination of Biochemical Oxygen Demand, F. W. Molhman, Referee

Various investigations have been made during the past year concerning the technique and interpretation of the biochemical oxygen demand determination. The most extensive work has been done by E. J. Theriault in the laboratory of The United States Health Service at Cincinnati, by R. E. Greenfield and A. L. Elder at the Illinois State Water Survey, and by various investigators in the laboratories of the Sanitary District of Chicago. Results of work done in the first two laboratories have been published under the following titles: "The Rate of Deoxygenation of Polluted Waters," Emory J. Theriault (Proc. Amer. Soc. Civ. Eng., 51, 9, 1819–28, November, 1925); "Effect of Temperature on Rate of Deoxidation of Diluted Sewage," R. E. Greenfield and A. L. Elder (Jour. Ind. and Eng. Chem., 18, 3, 291–2, March, 1926).

Very important facts have been brought out in both investigations concerning oxygen demands over long periods of incubation, up to 180 days. Results have shown that the demand for oxygen is far from being satisfied in twenty days at 20°C., but that absorption takes place in two stages, the first extending over ten days at 20°C., the second over a period of months. In explanation of the secondary phase, Theriault believes that it is the stage of nitrification, while the first phase is the stage of carbon oxidation; Greenfield and Elder believe the secondary phase is primarily the demand of dead organisms. The latter investigators claim the second stage was not obtained with sewage, but only with river water, while Theriault claims to have had similar results both with sewage and river water. This divergence of opinion must be reconciled by further work.

The rates of satisfaction at various temperatures have been determined, and are reported in both papers.

In the laboratories of the Sanitary District of Chicago comparative studies are being made (1) of the nitrate and dilution methods, (2) of the rates of satisfaction for raw sewage, effluents and river water, and (3) of the use of various types of diluting water. The present indications are that: (1) Results by the nitrate method are from 10 to 20 per cent lower than by the dilution method (5 or 10 days at 20°C.). (2) With fresh sewage or recently polluted water the rate of satisfaction of demand follows a logarithmic curve, but with nitrified effluents and river waters that have undergone considerable self-purification the rate of satisfaction is approximately uniform or straight-line. (3) Various types of dilution waters give variable results. Distilled water has given lowest demands, surface water highest, deep well and buffered distilled waters intermediate demands. Distilled water buffered with 500 mg. per liter sodium bicarbonate has been quite satisfactory. It has the advantage that it can be duplicated in different laboratories.

No results are now available concerning similar investigations in other laboratories. The referee would appreciate information regarding any work that has been done on this determination.

The Determination of Small Quantities of Phenols in Water Supply, E. C. Trax, Referee

Mr. Trax has been prevented from carrying out the work outlined on account of the pressure of personal business. He has, however, made a survey of the situation in the Pittsburg region and finds that taste and smell are largely depended upon in that vicinity to detect traces of phenols. The Folin and Denis reagent has been employed to some extent, but is not considered to be sufficiently accurate for the purpose.

The Field Representative, L. I. Birdsall

Mr. Birdsall has been able to put the Chairman of the Committee in touch with a number of water works men who were interested in different phases of work being investigated by the different Referees of Committee No. 1. The Referees concerned have been notified of the interest of the individuals mentioned, and it has been possible to secure coöperation from several of these.

RECOMMENDATIONS

Your Committee would recommend that the work at present being undertaken be continued, and that it be given authority to extend its operation to such additional subjects as may be advisable during the year, subject to the approval of the Standardization Council. It is recommended that the Committee shall coöperate in every way with the Committees on the Study of Boiler Waters, headed by Mr. S. T. Powell and Mr. Harold Farmer.

It is not considered that the work on any of the items in this list of subjects is sufficiently complete to be considered finished. Committee No. 1 would therefore suggest that the Committee be continued during the coming year.

Merritt Haviland Smith

Died December 9, 1926

Merritt Haviland Smith was born in New York City, on May 21, 1862. He was the son of Merritt Haviland and Mary Adelia (Howard) Smith. He graduated from Pennsylvania Military College with the degree of Civil Engineer in 1880. From 1880 to 1881 he studied law, and from 1881 to 1884 he was Engineer with the Pittsburgh and Western Railroad.

In 1884 he entered the service of the City of New York, in the Department of Public Works, and was engaged as Engineer on the work of the Croton aqueduct until 1890. In 1890 and 1891 he was engaged on general engineering work in connection with the development of lands in Florida, but in 1892 he returned to the service of the City in the Department of Finance, in which Department he continued until 1906. During this period he was also, from 1900 to 1902, Park Commissioner for the City of Yonkers and Police Commissioner for that City during 1905 and 1906.

In 1906, with the beginning of the work on the City's new water supply from the Catskill Mountains, he was appointed Department Engineer to the Board of Water Supply and placed in charge of the Southern Aqueduct Department, which covered all of that portion of the Catskill work from the Hudson River crossing south to the City line, including also Kensico and Hill View reservoirs. In 1910 he became Deputy Chief Engineer of the Board of Water Supply, and in 1914 was appointed Chief Engineer of the Bureau of Water Supply of the Department of Water Supply, Gas and Electricity, which Department has charge of the construction, maintenance and operation of the water supply systems of the five boroughs of the City.

On June 30, 1917, he was called into Federal Service, with the 104th Field Artillery, of which he was Colonel. On February 12, 1919, he was discharged from Federal Service, and returned to duty in the Department of Water Supply on February 13, 1919.

His long experience in military service began when he became a member of 7th Regiment, N. G. N. Y. in 1880. He served with Squadron A from 1896 to 1907, and for about six months of this period was Captain and Major, respectively, of the First United States Volunteers in Porto Rico during the Spanish-American War. He resigned from Squadron A as Captain in 1907, and re-entered the service again as Captain of the First Calvary early in 1912, and shortly thereafter was promoted to Lieutenant-Colonel. In 1914 he was made Lieutenant-Colonel of the First Field Artillery and Colonel of that organization in 1917.

He was a member of the American Society of Civil Engineers, the American Water Works Association, the Municipal Engineers of the City of New York, the American Society of Mechanical Engineers and the Chamber of Commerce of the State of New York.

On August 1, 1914, he was appointed Chief Engineer of the Department of Water Supply, Gas and Electricity.

On June 19, 1916, he was ordered to the Mexican border with First Field Artillery, N. G. N. Y., and entrained with his regiment for Texas July 3, 1916.

On October 9, 1916, he returned to duty in the Department of Water Supply after his return from the Mexican border and finally, on November 15, 1916, he was mustered out of the Federal service.

Colonel Smith on December 30, 1890, married Maude M. Underhill, by whom he is survived. The children of this union were Merritt Haviland, Jr., born 1891, died during the World War at Plattsburg, N. Y., and Roderick Ray, died in infancy.

Colonel Smith was a man of outstanding ability and personality. Of military bearing, strong and vigorous in every action, jovial and filled with life and humor, his friends were legion.

His last illness began in September of this year and he was retired from active duty with the City of New York on December 3rd. after a continuous service of 40 years.

Wm. W. Brush.

SOCIETY AFFAIRS

IOWA SECTION

The twelfth annual meeting of the Iowa Section, was called to order by Chairman Homer V. Knouse in the Adam Room of the Hotel Statler at St. Louis, Missouri on Wednesday, November 3. Honorable Victor J. Miller, Mayor of St. Louis, delivered the address of welcome on behalf of the city. Chairman Knouse reponded to Mayor Miller's address on behalf of the Section. (Sixty present.)

Topic No. 1, Low Water Difficulties, was discussed by C. L. Ehrhart, John W. Pray, G. W. Cox, E. E. Wolfe, H. V. Pedersen, N. T. Veatch, Jr., W. V. Wier, Frank Lawlor, Charles R. Henderson, W. R. Gelston, A. V. Graf, L. I. Birdsall and H. V. Knouse.

Topic No. 2, Taste Troubles During the Past Year, was discussed by Jack J. Hinman, Jr., E. E. Wolfe, A. V. Graf, J. W. McEvoy, R. J. Paulette, H. H. Gerstein, L. I. Birdsall, N. T. Veatch, Jr., M. E. Flentje, W. V. Wier and W. R. Gelston.

Additional topics discussed were Water Proof Paints, by N. T. Veatch, Jr., and C. L. Ehrhart, and Electric Pumping vs. Steam Pumping, E. E. Wolfe, R. L. Baldwin, C. L. Ehrhart, W. P. Brittain and W. R. Gelston.

The Round Table Discussion was discontinued at noon and the meeting adjourned until 2:00 o'clock. Chairman Knouse appointed the following committees to report at the afternoon session of November 4:

Resolutions Committee: Chas. R. Henderson, N. T. Veatch, Jr., G. W. Cox.

Nominations Committee: Frank Lawlor, E. E. Wall, H. V. Pedersen.

Auditing Committee: C. L. Ehrhart, E. E. Wolfe.

The Section reconvened at 2:15 p.m., with forty-three present. The following papers were read:

Conservation of Iowa Water Resources, H. V. Pedersen.

Following Mr. Pedersen's paper a few remarks were made by Beekman C. Little, Secretary of the American Water Works Association, who had just arrived at the meeting place.

Unusual Operating Features of the Centralia, Illinois, Filter Plant, R. S. Rankin, read by William E. Stanley, in the absence of Mr. Rankin.

Highway Water Supplies in Missouri, W. Scott Johnson.

Lactose Brilliant Green Bile as an Aid in the Tests for Bact. Coli, Dr. Max Levine. The paper to have been presented by Dr. Levine was not presented, owing to the absence of Dr. Levine. Instead of the paper, a summary of the work on lactose brilliant green bile by Committee No. 1 of the American Water Works Association was given by Jack J. Hinman, Jr., Chairman of Committee No. 1.

An Unusual Swimming Pool Filter Plant Based on Experience at the University of Iowa, Jack J. Hinman, Jr.

The Section adjourned at 5:00 o'clock to meet again in the evening.

The evening session was called to order by Chairman Knouse at 8:15 p.m. and the following papers were presented:

Reminiscences of a Water Works Man, Dow R. Gwinn.

A Program for the Protection of Land Tunnels in Chicago, H. H. Gerstein and Arthur E. Gorman.

Sedalia, Missouri's New Half Million Dollar Water Supply (with Motion Pictures), R. E. McDonnell. This paper was read by R. L. Baldwin, in the absence of Mr. McDonnell.

The evening session adjourned at 10:00 o'clock. (Sixty-three present.)

The morning session of November 4 was opened by Chairman Knouse at 9:30 a.m. (Sixty-two present.) The following papers were presented:

Calcium and Magnesium Hydrates as Coagulating Agents, Martin E. Flentje.

Notes on the Operation of the New Water Softening Plant at Springfield, Illinois, Charles H. Spaulding.

Stream Pollution and its Effects, N. T. Veatch, Jr.

Cost Accounting on Pipe Laying Jobs, Homer V. Knouse.

The meeting adjourned at noon.

The reading of papers was again taken up at 2:15 p.m. (Sixty-nine present.)

The Franchise of the Citizens Water Company of Burlington, Iowa, Frank Lawlor.

The New Missouri River Plant, Howard Bend, L. A. Day.

The Dorr Clarifier as an Aid in Water Treatment, John Fleming.

The Pitometer Survey as an Aid in the Improvement and Maintenance of the St. Louis Distribution System, Meyer Serkes.

The American Water Works Association and its Contribution to the Water Supply Industry, Beekman C. Little.

Following Mr. Little's remarks the Section went into business session.

As none of the members of the Resolutions Committee were able to be present, the report of the committee was read by the secretary. It was moved by Mr. Jensen, seconded by Mr. Molis, that the report be approved. Carried. The report of the committee carried the following resolutions:

I. *Be It Resolved* by the Iowa Section of the American Water Works Association, that the convention held in St. Louis November 3, 4 and 5, 1926 has been a satisfactory and profitable meeting in every way. And that the members of the Section are grateful to all those who contributed time and effort in planning and carrying out the arrangements, and that the Secretary is hereby requested to extend the thanks of the Section to the proper persons.

II. *Be It Resolved* by the Iowa Section of the America Water Works Association that the Section hereby tenders its thanks and expresses its appreciation to its Chairman, Homer V. Knouse and its Secretary, Jack J. Hinman, Jr., for their unselfish services and their loyal devotion to our interests.

III. *Be It Resolved* by the Iowa Section of the American Water Works Association that the Section hereby expresses appreciation to Beekman C. Little, Secretary of our Mother Association and to other members of the American Water Works Association not belonging to the Iowa Section for their presence at this meeting and their help in making its a success.

IV. *Be It Resolved* by the Iowa Section of the American Water Works Association that whereas a motion was passed at the last meeting instructing the Secretary to inform the proper officers of the American Water Works Association that it was the desire of this Section that the next annual convention be held in Chicago, and whereas Chicago has been selected, that each member of the Iowa Section make definite plans for attending, as Chicago is almost within our own territory, and the Iowa Section should use every effort to make the convention held there successful.

The Nominating Committee, by Frank Lawlor, Chairman, brought in the following recommendations: For Chairman, J. W. McEvoy; for Vice Chairman, Thomas J. Skinker; for Directors, John W. Pray, W. Scott Johnson. It was moved by Mr. Lawlor, seconded by Mr. Jensen, that the Secretary be instructed to cast a unanimous ballot for the proposed officers. The motion was unanimously carried.

The Auditing Committee, C. L. Ehrhart, E. E. Wolfe, by Mr.

Ehrhart, Chairman, reported that the books of the Secretary had been inspected and found correct. The report was accepted.

J. Chris Jensen, of Council Bluffs, extended an invitation to the Section to meet in Council Bluffs in 1927.

It was moved by Jack J. Hinman, Jr., seconded by Mr. Lawlor, that the members of the Section residing in western Nebraska be released to the Rocky Mountain Section as a sectional organization more likely to be of service to them. It was explained that the release of these members was at the desire of the Rocky Mountain Section with the approval of the National Executive Committee. The motion was carried.

It was suggested by Mr. Lawlor that all members of the organization be urged to see to it that their local libraries carry copies of the Manual of the American Water Works Association on their shelves. The usefulness of such an arrangement in advising the public concerning current methods of water treatment was emphasized.

Announcements were made concerning the meeting of the American Water Works Association at Chicago, the Iowa Sewage Conference at Ames, the Missouri Water Works Operators School at Jefferson City and the Kansas Water Works Operators School at Lawrence. The meeting was adjourned at 5:30 p.m.

The annual dinner given by the Manufacturers' Agents was held in the Ball Room of the Hotel Statler at 6:30 p.m., November 4. An excellent dinner was served, following which there were a few short talks. An entertainment program was provided by professional entertainers secured by the Manufacturers' Agents.

At 9:00 o'clock on the morning of November 5 the members of the Section met in the lobby of the Hotel Statler and were taken by automobile to the Chain of Rocks Filter Plant for an inspection trip. Following the inspection trip the party was driven to the Garivelli Restaurant for luncheon.

In the afternoon the party drove to the new Missouri River Plant under construction at Hine. On the way to the filter plant the new one hundred million gallon service reservoir now under construction was visited. A feature of the inspection of the Missouri River Plant was the opportunity to see the driving of a seventy-five foot concrete pile for the foundation of the building which will house the wash water tanks of the new filter plant. The members of the Section disbanded following the inspection trip.

JACK J. HINMAN, JR.
Secretary.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

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Chlorine Studies and some observations on taste producing substances in water, and the factors involved in treatment by the super- and de-chlorination method. Norman J. Howard and R. E. Thompson. Can. Eng., **51:** 16, October, 1926. Paper presented at forty-fifth Convention New England Water Works Association, Providence, R. I., September, 1926. Work carried out in Toronto Laboratories has resulted in great economies in plant operation. Deals with tastes and odors in chlorinated water resulting from phenoloid substances and those of unknown origin only. Taste toubles in Toronto date back to time when sterilisation of water with calcium hypochlorite was first applied in 1910. Liquid chlorine lessened number of complaints. Taste of great intensity has periodically occurred and experimental work showed that super- and de-chlorination of the water offered a successful method of abating the condition. In the spring of 1926 a sum of $32,000 was voted for one year's treatment. Public objection to the addition of further chemical to the water resulted in the treatment being temporarily held up. A wave of taste occurred in the late summer months which was responsible for the commencement of the new process in September. The causes of the medicinal taste and odor in chlorinated water are given, with a résumé of the literature during past eight years. Decomposition of organic matter is said to produce phenoloid substances in solution. Waters either of low organic matter and free of color, or very high in organic matter, are those most liable to taste. Sodium iodide, used as prophylactic against goitre, may cause taste in chlorinated water when present in quantities as low as 10 parts per billion. Wide variations in the organic and mineral content between one supply and another do not allow of comparisons being made, particularly as to liability to taste; neither can the susceptibility be gauged or explained in the light of current knowledge. Taste in water is seasonal, the least being reported during the warm summer months. In Toronto the most severe taste periods have occurred in spring and fall. Taste is attributed to combination of phenols with stirring up of organic matter during storm periods. Estimation of small amounts of phenol by distillation test is regarded as unreliable. Details of study on taste producing substances derived from destructive distillation of coal are given in detail. Some thirty substances were examined and taste production was practically confined to the mono-substitution group, including phenol, *ortho-meta-*, and *para-*cresol, xylenol, and anisole. Characteristic chemical taste of non-objectionable character was produced by thymol and guaiacol. Phenol, cresols, xylenol, and anisole caused the typical iodiform taste in chlorinated water. Experiments were made to determine the value of color reactions in differentiating taste producing substances by use of Folin-Dennis and Fox and Gauge reagents, but it was concluded that for this purpose the tests were of limited value. The super-chlorination method of Sir A. C. HOUSTON was found to be effective in destroying the taste-producing compounds which occur in the presence of phenol and chlorine. Two very definite conditions control the treatment, namely, a minimum quantity of applied chlorine and a definite time contact. Both of these factors must be determined upon a water supply before the treatment can be effective. An insufficient dose of chlorine or inadequate time contact will negative the treatment. In Toronto when dealing with filtered Lake Ontario water it was found that the minimum dose of chlorine varied between 10 and 12.5 pounds with a contact period of not less than one hour. Practice has shown that 12.5 pounds, or more, per million imperial gallons are necessary to destroy taste. The contact period can be greatly lessened by increasing the dose of chlorine. Two parts per million (20 pounds per million gallons) reduced the contact time on Lake Ontario water by thirty minutes. Large doses of chlorine, however, with short contact periods of ten minutes or less proved ineffective. Residual chlorine is removed by application of sulphur dioxide through a vacuum pedestal machine. A chart is given showing various doses of phenol and cresol, the requisite amounts of chlorine and the time factor involved. Cresol takes considerably less time to destroy than phenol. The super treatment was applied on a large scale in Toronto for two weeks continuously in September, 1926. It is now in continuous use, over 70 million gallons being treated daily. Control water indicated that taste would have occurred in the city supply without treatment on five out of twelve days. Estimated cost of new process is $32,000 per annum equivalent to approximately $0.80 per million gallons of water treated. Problems encountered during treatment included difficulty in maintaining cylinder gas pressure (sulphur dioxide) under high discharge conditions. This was overcome by maintaining room temperature in excess of 80°F. More sulphur dioxide was required to remove chlorine than the amount theoretically necessary, which is 32 pounds of sulphur dioxide to 35.5 of chlorine or a ratio of 0.9 to 1.0, owing to partial oxidation of the sulphurous acid by the dissolved oxygen in the water. Slight increase takes place in the non-carbonate hardness, consisting of calcium chloride and calcium sulfate and in free carbonic acid with corresponding decrease in carbonate hardness. This is approximately only 25 per cent of the normal change in hardness when alum is applied in doses of 1 grain per gallon. Dilution of super-chlorinated water before de-chlorination with untreated water is not recommended. Experiments showed that the residual chlorine in the treated water was at times just sufficient to cause taste in the whole supply when diluted with untreated water. Hydrogen-ion experiments suggested by LINN H. ENSLOW showed that when filtered water to which 0.010 parts of phenol had been added was treated with 0.25 parts of chlorine, and the pH adjusted to 5.8 with sulphuric acid no taste occurred, whereas the same sample at the normal pH of 7.7 tasted badly of iodoform. The sample which had been adjusted with sulphuric acid when restored to its original pH value remained tasteless. Waters must be acid or highly alkaline to avoid taste. This is important in the treatment of waters of low pH value in which alkali is employed for lessening corrosiveness. In such cases the application of chlorine prior to increasing the pH value may be a means of avoiding taste troubles. Important observations are recorded relative to the effect of sunlight on color reaction when using the *o*-tolidine method for determining free chlorine. The exposure of water containing free chlorine and *o*-tolidine to direct sunlight, interferes with the production of color and may result in grave inaccuracies being recorded. Sunlight conditions must be carefully controlled if accurate results are to be obtained. The effect is due to interference with color production and not increased rate of chlorine absorption. Detailed experiments and figures are given. A summary of all results follows with conclusions. We found in Toronto, that the post-chlorination process was more effective than the pre-chlorination treatment when applying excess chlorine (through drifting-sand plant where sedimentation is not employed). In water heavily polluted, there are probably many other substances which act on chlorine and interfere with its oxidising properties. The removal of these substances by coagulation and filtration allows the chlorine to act more directly on the phenoloid substances. In all our work we have failed to find any taste producing substance derived from the destructive distillation of coal which did not respond to the excess chlorine treatment. Tribute is paid to the work of Sir A. C. HOUSTON whose active researches formed the basis of the Toronto work.—*Norman J. Howard.*

Additions to Seattle Works. Eng. News-Rec., 96: 867, May 27, 1926. In development of Lake Youngs, Seattle, Wash., 2 earth-fill dams have been constructed which will raise lake level about 20 feet and provide available storage of 4,000 m.g. Outlet tunnel, which is concrete-lined, 8 feet in diameter and 11,000 feet long, has also been completed. A 54-inch steel pipe line 5 miles long will be constructed from existing Cedar River pipe lines to reservoirs in north end of city, and a 10-mile gravity aqueduct from Cedar River to Lake Youngs is proposed. To serve higher levels there are being provided two 1-m.g. standpipes and two 2,000-g.p.m. pumps driven by 300-h.p. motors, each operating under 270-foot total lift.—*R. E. Thompson.*

Hetch-Hetchy Progress. Eng. News-Rec., 96: 867, May 27, 1926. Preliminary work on San Joaquin section of Hetch Hetchy aqueduct is progressing under $10,000,000 bond issue voted by San Francisco late in 1924. Bond issue of $23,000,000 to complete this aqueduct will be requested about 3 years hence.—*R. E. Thompson.*

Good Progress on East Bay Project. Eng. News-Rec., 96: 867, May 27, 1926. Mokelumne River project for ultimate 200-m.g.d. supply through 90-mile conduit to East Bay Municipal Utilities District has progressed in 42-mile section between the district and San Joaquin River, from which emergency supply may be taken.—*R. E. Thompson.*

Los Angeles Reaching Out for Colorado River. Eng. News-Rec., 96: 867, May 27, 1926. Completion of St. Francis dam adds 38,000 acre-feet to capacity of Los Angeles aqueduct storage system, which now comprises 12 reservoirs holding 30,000 m.g. All the city's present sources can be depended on to produce only 300 m.g.d. During 3-month period last year domestic consumption averaged 146 m.g.d., and maximum was 205 m.g.d. Bond issues totalling $2,100,000 for proposed Colorado River aqueduct were voted in 1924 and 1925 and plans are being prepared for this project which involves an infiltration canal along river.—*R. E. Thompson.*

Specifying Concrete by Water-Cement Ratio Alone. F. R. McMillan. Eng. News-Rec., 96: 698–700, 1926. Procedure employed in applying specifications based solely on water-cement ratio in construction of new building of Portland Cement Association in Chicago is described. The proportion of aggregates was governed entirely by the requirements of workability, with single limitation that the coarse aggregate should not be less in amount than the fine, nor more than twice the fine. The maximum water-cement ratios specified were: (1) for 2900 pounds per square inch concrete, 6 U. S. gallons per sack (94 pounds) of cement; (2) for 2000-pounds per square inch concrete, 7¼ gallons per sack. A curve for proportioning concrete by water-cement ratio is given and its application to small jobs is described.—*R. E. Thompson (Courtesy Chem. Abst.).*

Flow of Water in 54-Inch Concrete Conduit, Denver, Colo. Fred C. Scobey. Eng.-Rec., 96: 678–80, April 29, 1926. Flow tests on 54-inch concrete conduit constructed by Denver municipal water works in 1921 and 1924 are described. These and similar tests carried out on same size pipe at Tulsa, Okla., in 1924, indicate that Scobey formula, with coefficient $C_s = 0.370$, is very conservative. Capacity found was 15 per cent greater than that accepted for best conduit a few years ago. It was observed that the 1921 pipe had lower friction factor than 1924 pipe, probably due to very thin but slick coat of slime in former. Pipe line, which will ultimately extend from Kassler filters to Capitol reservoir, was constructed of precast units in 12-foot lengths, heavily reinforced with steel hoops. Joints, which were filled with neat cement after placing lead gasket and calking, can be located by color only, not by touch. Life of pipe is estimated at 70–100 years.—*R. E. Thompson.*

Pipe Drilling Standard Holds Two Drills. W. W. Monk. Eng. News-Rec., 96: 871, May 27, 1926. Brief illustrated description.—*R. E. Thompson.*

New Bay City, Mich., Water Works Displaces Two Old Plants. J. W. Ellms. Eng. News-Rec., 96: 682–3, April 29, 1926. Bay City is divided into two sections by Saginaw River, and each section was formerly supplied from a separate water works. New plant, which supplies entire city, consists of new intake crib 4000 feet from shore in Saginaw Bay, 48-inch lock-bar steel intake pipe, 2 hydraulic-jump mixing flumes, 2 baffled 2-m.g. coagulation basins, providing detention period of nearly 5 hours at maximum plant capacity of 20 m.g.d., ten 2-m.g.d. mechanical filters designed for high velocity wash, and a 4.8-m.g filtered water reservoir. One manifold serves all laterals of filter strainer system, which was designed on basis of experiments which showed that correct ratio of cross-sectional area of manifold to sum of cross-sectional areas of laterals for uniform distribution is 2:1. Gravel and sand layers are 20 and 30 inches in thickness respectively, former being graded from $\frac{1}{8}$ to $2\frac{1}{2}$ inches in diameter and latter having effective size of 0.36 mm. and uniformity coefficient of 1.74. Adjustable gutters permit variation in rate of back-wash.—*R. E. Thompson.*

Albuquerque, N. M. Eng. News-Rec., 96: 694–5, April 29, 1926. Water supply of Albuquerque is obtained from 35 wells varying in depth from 60 to 200 feet. Town is 100 per cent metered and average per capita consumption is 100 gallons daily, maximum being 175 gallons. Minimum water rate is $1.70 per month for 6000 gallons, with rate of 15 cents per 1000 gallons above this amount in summer and 30 cents in winter. Estimated population is 26,000.—*R. E. Thompson.*

Giants Spread Car-Dumped Fill for Alouette Dam. C. E. Blee. Eng. News-Rec., 96: 696–7, April 29, 1926. Construction of Alouette dam of British Columbia Electric Railway Co., Ltd., is described and illustrated. Dam consists of earth fill placed by semi-hydraulic method, 1000 feet long on crest with maximum height of 63 feet above stream bed, upstream face of which is paved with hard hand-placed rock.—*R. E. Thompson.*

Uniform Aggregate Important in Concrete Control. Stanton Walker. Eng. News-Rec., 96: 728, May 6, 1926. It is emphasized that knowledge gained by recent researches on concrete control does not eliminate necessity of employing properly prepared and graded aggregates.—*R. E. Thompson.*

Manifold and Anchorage Combined in Pit Three Penstock. Eng. News-Rec., 96: 728–9, May 6, 1926. Brief illustrated description of transition from 19-foot concrete-lined tunnel to three 10 foot 9 inch steel penstocks in recently completed Pit 3 plant of Pacific Gas and Electric Co.—*R. E. Thompson.*

Jarvis's Study of Flood Flow Extended. Eng. News-Rec., 96: 737, May 6, 1926. Flow formula advocated by C. S. Jarvis: $Q = p\ 10{,}000 \sqrt{M}$, where Q is maximum flow in second feet, M, drainage area in square miles, and p, that fraction of maximum flow possible in any region that occurs in the particular region or particular stream involved, was found to give results for 5 streams which agreed with data in possession of others. Values of p adopted were estimated from known flood flows of nearby streams, and ranged from 0.10 to 0.48. Percentage values of this fraction has been found to be roughly equal to average annual run-off (inches) for drainage area.—*R. E. Thompson.*

Flood-Protection Plan Proposed for Paris District. E. Maynard. Eng. News-Rec., 96: 773, May 13, 1926. It is planned to intercept waters of Marne River at Neuilly, and by means of regulating dam carry flood waters first through section of gravity canal, then raise them by electrically-driven centrifugal pumps to small divide, whence by pipe and open channel they will be diverted into Seine at La Briche. Cost of entire works is estimated at 285,000,000 francs, plus 7,500,000 for power for operation during period of 25 days, the average time of flood danger.—*R. E. Thompson.*

Replace Cast-Iron Turbine Runners Quickly After Failure. Eng. News-Rec., 96: 764, May 13, 1926. Cast-iron runners of the two 20,000-h.p. vertical reaction turbines of Copco No. 2 plant of California Oregon Power Co. on Klamath River, failed in service November 7, 1925, and January 17, 1926, respectively. Replacement was made in 60 days from time of first shutdown. —*R. E. Thompson.*

Old Earth Dam on the Pequannock in Northern New Jersey. J. ALBERT HOLMES. Eng. News-Rec., 96: 765, May 13, 1926. Brief illustrated description of old dam on Pequannock River constructed of glacial drift.—*R. E. Thompson.*

Pneumatic Filter-Alum Conveyor for Minneapolis Water Filters. J. A. JENSEN. Eng. News-Rec., 96: 766–8, May 13, 1926. New Fridley 40-m.g.d. (160 m.g.d. ultimate) filter plant at Minneapolis will supplement supply from filters at Columbia Heights. Source of supply for both plants is Mississippi River. The pneumatic conveyors installed, with which granulated alum can be moved from cars to primary storage, or from cars and primary storage to service hoppers, at rate of 12 and 8 tons per hour respectively, are described and illustrated. It has been guaranteed that loss due to escape of dust will not exceed 0.1 per cent. Disadvantage of system where volumetric dry feed machines are employed is that stratification of coagulant interferes with accuracy of delivery. This will be remedied by method of checking by weighing.—*R. E. Thompson.*

Topeka, Kans. Eng. News-Rec., 96: 769–71, May 13, 1926. New $1,500,000 mechanical filter plant of 5-m.g.d. capacity was put in service in spring of 1924 for treating Kansas River water. Prior to this, water was drawn from 250 sand points placed along river, which finally became so clogged that sufficient supply was no longer available.—*R. E. Thompson.*

Lining an Earth Spillway Channel with Concrete. C. E. BLEE. Eng. News-Rec., 96: 777–8, May 13, 1926. Brief illustrated description of paving and lining of spillway of Alouette dam with concrete. Water drop of 38 feet was accomplished by means of ogee section, hydraulic jump being employed to dissipate destructive water velocities.—*R. E. Thompson.*

Arch Dam of Thin Section now in Service on Salt River. Eng. News-Rec., 96: 778, May 13, 1926. Brief illustrated description of Mormon Flat dam, completed last year on Salt River in Arizona, which increases storage capacity on irrigation project by 90,000 acre-feet and makes possible development of 20,000 h.p. Dam was designed by cylinder formula and stresses were calculated according to theory of the elastic arch. Height is 210 feet, with base thickness of 22 feet and thickness under roadway on crest of 8 feet. Crest length is 326 feet, exclusive of overflow gravity section which is 90 feet long, and maximum height, 93 feet. Total of 43,000 cubic yards of concrete was used in structure. Closure of spillway is effected by 9 Taintor gates, 27 feet long by 23 feet wide, weighing 27 tons each.—*R. E. Thompson.*

Lime-Silica Index as Measure of Cement Quality. THADDEUS MERRIMAN. Eng. News-Rec., 96: 648–50, 1926. The principal components of portland cement are (1) $3CaO \cdot Al_2O_3$, (2) $3CaO \cdot SiO_2$, (3) $2CaO \cdot SiO_2$, (4) MgO, (5) $3CaO \cdot Fe_2O_3$, and (6) $CaSO_4 \cdot 2H_2O$, of which only (2) and (3) are believed to possess cementing qualities, the former being the most important. The $CaO-SiO_2$ index is the percentage of CaO in the cement which is available for combination with the available SiO_2 divided by the latter; the available SiO_2 being the total SiO_2 less the insoluble residue, and the available CaO, the total CaO less that in combination with Al_2O_3, Fe_2O_3, and SO_3. A cement in which all the CaO is combined in form of the desirable $3CaO \cdot SiO_3$ would have an index of 2.80. The cement which shows the highest strength at 7 days for a given $CaO-SiO_2$ index, or the lowest index for a given strength, has been the most thoroughly made and calcined. It is therefore indicated that strength alone is not a criterion of either cement value or quality. Fine grinding will not compensate for either a deficiency of cement value or for underburning of product. The tensile strength and $CaO-SiO_2$ index for 298 cements are shown graphically. Practical applications of considerations advanced in the formulation of requirements of cement quality are outlined.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Chemical Cost for Reducing Water Hardness. Eng. News.-Rec., **96:** 726, May 6, 1926. Brief data regarding softening at Columbus, Ohio, is given. Cost of chemicals during 1925 was 10.2 cents for each part of hardness removed, compared with average of 10.24 cents for 17 years from 1909 to 1925. Minimum average annual cost was 5.2 cents in 1915 and maximum 15.3 in 1918. Average reduction in hardness during 1925 was 206, average hardness of raw water being 298.—*R. E. Thompson.*

Water Power Developments on the Salt River in Arizona. Eng. News-Rec., 96: 978–9, June 17, 1926. Brief data given on power projects on Salt and Verde Rivers.—*R. E. Thompson.*

Tests of Vibrolithic Concrete. L. W. TELLER. Eng. News-Rec., **96:** 779, May 13, 1926. The vibrolithic process was found to give a more uniform product, which exhibited greater strength at 28 days for a given cement content than normal concrete.—*R. E. Thompson* (*Courtesy Chem. Absts.*).

Denver Societies Hold Money Wasted on Flood Control Work. Eng. News-Rec., 96: 806–7, May 20, 1926. Notes from report of Colorado Engineering Council, comprising 14 engineering and technical societies, are given, in which city administration is severely censured for waste of money in building embankments which are "not of a sufficiently substantial nature to ensure the safe carrying capacity that otherwise would be possible with the levee heights adopted." Comprehensive engineering study of Denver flood problem is recommended.—*R. E. Thompson.*

Asphalt Grouting Under Hales Bar Dam. Geo. W. Christians. Eng. News-Rec., 96: 798-802, May 20, 1926. During construction of Hales Bar concrete dam over Tennessee River at Guild, Tenn., great difficulty was experienced in getting foundations down to satisfactory bed rock, and pneumatic caissons were sunk throughout most of dam. On completion of work considerable leakage developed, and after various methods to correct this condition had failed, holes were drilled from tunnel in dam into rock below in endeavour to locate sections through which leakage was occurring. Crevices in the rock were found within fairly well defined limits, which are believed to be due to solution and disintegration which proceed in advance of mechanical erosion by river flow. The condition does not materially affect stability or permanence of dam. One exceptional crevice showed water flow velocity of about 360 feet per minute. Instruments devised for investigation, a crevice meter and a flow meter, are described. Fissures were sealed by means of asphalt grouting. Procedure employed, for which patents have been granted, is described in detail. Advantages of method over cement grouting are outlined. All of leakage was not remedied, but it was reduced to such an extent that it was thought that expense of locating remainder was not justified. Method was also used to stop leaks on cliff face, against 150-foot difference in water level, below another dam.—*R. E. Thompson.*

Adaption of Slide Rule for Computing Flow in Pipes and Open Channels. J. B. Lippincott. Eng. News-Rec., 96: 658-9, 1926. A curve showing the approximate relation of Williams and Hazen's "c" and Kutter's "n" for open channels is given which was prepared to facilitate computation of flow with the Williams and Hazen slide rule.—*R. E. Thompson* (*Courtesy Chem. Absts.*).

Factors Considered in Designing Largest Pumping Station. Loran D. Gayton. Eng. News-Rec., 96: 838-53, May 27, 1926. Factors considered in determining the need and location, tunnel requirements, and equipment for the 300-m.g.d. Western Ave. Station, Chicago, are discussed in detail. Steam-turbine-geared centrifugal pumps were selected as being most economical in overall operating costs. While triple-expansion pumping engines are by far the most economical in steam consumption, initial cost, buildings required, labor cost, etc., make cost of operation of these units 14 per cent higher than that of turbo-centrifugals. Cost of operation of Diesel station is approximately same as of steam-turbine station, but mechanical difficulties involved prohibit employment of former. Cost of operation of motor-driven centrifugals is about 10 per cent higher than of steam-turbines. Study of load curve showed that 3 pumps having capacity range of 50-75 m.g.d. and total head range of 107-150 feet would give ideal operating conditions. Fourth unit was added for reserve. Specifications for turbines, gears, pumps, and condensers are given. Lowest bid received was for compound turbines with guaranteed water rate of 9.5 pounds per h.p.-hr., or duty of 208,000,000 foot pounds per 1000 pounds of steam at most efficient point. Details of steam generating equipment are included. Mechanical stokers, powdered coal, and oil-fired boilers were considered, stokers being adopted. In Chicago, with bituminous screenings at $2.90 per ton and oil at 5 cents per gallon, cost of steam from fuel oil is approximately double that from coal. An evaporator plant was installed for distilling make-up water, which amounts to 2 per cent. Estimation of relative costs of distillation and zeolite softening indicated that annual operating costs would be $500 less with former method, representing net earning of 12.8 per cent on added investment of $4000 to purchase evaporator plant. Project is about 60 per cent completed.—*R. E. Thompson.*

Experience with Riveted Pipe in San Francisco Water Works. Geo. W. Pracy. Eng. News-Rec., 96: 844–6, May 27, 1926. Riveting of plates into cylinders and joining then to form pipes was originated by a miner in early days of California. Herman Schussler, who entered employ of Spring Valley Water Company in 1864, developed the idea until by 1875 a considerable mileage of riveted pipe was in use. Experience with such pipe of 16–44 inches diameter, some of which has been in use 54 years, indicates that riveted pipe is preferable to cast-iron pipe in most cases. Prior to 1907, all riveted lines laid, except submarine pipes, were made of best grade laminated wrought iron. Since that date steel has been employed. During past 16 years, only trouble experienced has been in 2 sections within limited districts which were affected by electrolysis. Both these lines passed directly in front of a substation. Bonding of pipes to electric return system eliminated difficulty. Estimated relative net costs of large mains after 40 years' use, on basis of installations of latter made during past few years, are $418,800 and $278,800 respectively, for cast iron and riveted pipe. Most important element in prolonging life of thin metal pipe is the dip, including prevention of damage to same during installation. Lately all pipes have been wrapped with prepared paper almost identical with roofing felt, in addition to being dipped in asphalt. —*R. E. Thompson.*

Well-Water Development with Air Lifts at Lansing, Mich. L. R. Howson Eng. News-Rec., 96: 846–8, May 27, 1926. History of water supply of Lansing is reviewed. In recent study, additional wells were selected as source of increased supply in preference to filtered and chlorinated supply from Grand River, owing to natural purity of ground water and its constant temperature of about 50°F. Temperature of river water varies from 32° to 80°. New Riverside Station development consists of 12 wells located in straight line parallel to Red Cedar River at intervals of 300–400 feet. Air-lift method of pumping was selected as this system possesses following advantages over electrically-driven deep-well turbines: (1) lower annual cost; (2) greater reliability; and (3) greater flexibility. Tests of air-lift equipment showed overall efficiencies of 34 per cent. Cedar St. station was also rehabilitated and equipped with air-lift apparatus. Hardness of supply is, 330 p.p.m. Softening will probably be employed in near future.—*R. E. Thompson.*

Charleston, S. C. Builds 2,000,000-Gallon Elevated Steel Tank. Eng. News-Rec., 96: 848–9, May 27, 1926. Illustrated description of 2,000,000-gallon elevated tank on 80-foot tower, which is probably largest elevated tank with self-supporting bottom built to date. Tank shell above curved bottom is 80 feet in diameter by 35 feet high, and is not surmounted by roof. Ellipsoidal bottom is 26 feet, terminating in 14-foot steel riser pipe 54 feet high. Overflow trough is 18 inches by 18 inches, with 12-inch galvanized iron down pipe. Total weight of steel in structure is 1,350,000 pounds, and total water load 17,000,000 pounds. Steel in tank, cylinder and overflow trough is of copper-bearing grade. Exterior will be painted with 2 coats of red lead, and finishing coat of aluminum. Bitumastic enamel will be applied to interior. Tank was constructed to relieve wide fluctuations in pressure and load on pumping station caused by irregular demands by industrial plants, which consume approximately one-third of total water supplied.—*R. E. Thompson.*

Unique Reservoir Lining for Port Angeles, Wash. M. P. Hatcher and E. L. Ferguson. Eng. News-Rec., 96: 859–61, May 27, 1926. Port Angeles, a city of 10,000 people, recently completed a water works program involving expenditure of $625,000, about $280,000 of this amount being paid for privately owned system and remainder for development of new 11-m.g.d. supply, 6-m.g. reservoir, and improvements to distribution system. With old supply of 3 m.g.d., city has total available supply of 14 m.g.d. or 1400 gallons per capita. New supply is taken from Morse Creek. Concrete dam about 8 miles from city diverts water through 24- and 20-inch gravity wood conduit to reservoir, from which water flows by gravity to distribution system. Reservoir is in excavation and embankment, with side slopes of 1.75 to 1 and top embankment width of 15–30 feet. Slopes are lined with reinforced concrete slabs 5 inches thick, and bottom with 6-inch slabs. Lining is described in detail. Total cost of reservoir was $70,000.—*R. E. Thompson.*

Prehydration of Cement in New Method of Concrete Mixing. Willard B. Jones. Eng. News-Rec., 96: 850 (1926). During the construction of the Montebello filtration plant at Baltimore, Md., a large part of concrete was mixed by hydrating with required amount of water prior to mixing with the aggregate. This method produces a product of uniformly good quality, eliminates possibility of lumps of cement in the concrete, provides facilities for handling the grout when bonding new concrete with an old pour, and makes possible a decided reduction in time of mixing. Fifteen seconds in mixer was found to be sufficient to give concrete of normal strength. The prehydration process and machine employed, which is described, have been patented.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Building Cellular Wall Cofferdam, St. Louis Intake. John C. Pritchard. Eng. News-Rec., 96: 862–5, May 27, 1926. Construction of intake and pump pit for St. Louis intake at Howard Bend on Missouri River is described and illustrated. Elevation of river bank at site is about 42, and extreme high and low water levels, 43 and 11 respectively. Bottom of low service pit was made 0.5 and ultimate depth of excavation, 14. Entire site, which is partly inshore and partly in river, was excavated to El. 30, to reduce depth of cofferdam. Owing to dimensions, a cellular cofferdam was adopted, consisting of 30 closed cells. Steel piles weighing 38 pounds per foot, 56 feet in length, were employed total number being 1666. High service pit, located immediately behind low service pit, was also cofferdam job, but this was much simpler and depth was 29 feet less, permitting use of single line of 34-foot piles.—*R. E. Thompson.*

"Multiple-Dome" Design Adopted for Coolidge Dam. Eng. News-Rec., 96: 865, May 27, 1926. Multiple-dome design has been adopted for Coolidge Dam across Gila River in irrigation and flood conservation project in Arizona. Design differs from ordinary multiple-arch design in magnitude of its arch spans and in doming of arches in vertical plane.—*R. E. Thompson.*

Weir-stick for Use on Narrow Canals or Streams. T. A. HAYDEN. Eng. News-Rec., 96: 850–1 (1926). The Clausen Pierce weir stick, designed by I. M. CLAUSEN and RALPH PIERCE, consisting of rod 5 feet long, 1 inch thick, and 1⅜ inch wide, graduated in Miners' inches per inch width of weir, is described. The rod, which can be used on any narrow ditch where a weir or gate with free fall exists, or can be installed, has greatly facilitated the operation of the Salt River irrigation project.—*R. E. Thompson (Courtesy Chem. Abst.).*

Moot Questions on the Design of Lake Intakes. PAUL HANSEN. Eng. News-Rec., 96: 861–2, May 27, 1926. Brief discussion of design of intakes in which tabulated data is given for number of existing structures. Depth should be sufficient to avoid influence of wave action, undertow, and resulting turbidity. In Lake Michigan these influences probably do not extend below 40 feet. Difficulties due to frazil ice may be avoided by extending intake to depth such that vortices cannot reach from surface to intake level. Depth required is not definitely known, but not many intakes give trouble at 30 feet or more. Extending Marquette, Mich., intake to depth of 56 feet was unsuccessful in avoiding phenol wastes and zone of seasonal turn-over. If intakes are placed at reasonable depth it is questionable if any special form of intake structure is necessary. An intake well decreases the capacity of an intake, even when maximum feasible siphon action of downturned inlet pipe is utilized. At South Haven, where intake tends to fill with sand, it has been found that an adequate volume of water with but little more sand can be obtained more readily by direct pumping from intake pipe than by pumping from intake well. At Lake Forest it was found that with centrifugal pumps more water and better pumping conditions could be obtained by connecting pumps directly with the intake.—*R. E. Thompson.*

Detroit Experimental Filter Plant. Eng. News-Rec., 96: 871, May 27, 1926 Brief illustrated description of Detroit experimental filter plant which was constructed for studying design of coagulation and sedimentation basins.—*R. E. Thompson.*

Town of 4,000 Spends $90 per Capita for Water and Sewage. WEBSTER L. BENHAM. Eng. News-Rec., 96: 852–5, 1926. The new water supply system of Elk City, Okla., consists of a dam impounding water from a drainage area of 23½ square miles in a reservoir of 250 million gallons capacity, aërator, mixing chamber, coagulation basins, two 0.5-million gallons per day mechanical filters, and chlorination equipment. The cost of the entire project, including extensions to the distribution system and sewer improvements, was $356,000. Dam is of earth, with concrete cut-off core-wall, approximately 850 feet in length, and there is also a shallow dike about 1000 feet long. Maximum height of dam is 30 feet, and width at top is 16 feet. It was necessary to carry core-wall to depth of 30 feet below ground level for several hundred feet to prevent loss of water. Slope of water side was made 3 to 1, and that of downstream side, 2 to 1, former being paved with reinforced-concrete slabs 4 inches thick, laid in sections with expansion joints of asphalt.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Baffle Piers at Toe of Dam Dispel Energy of Flow. I. C. Steele. Eng. News-Rec., 96: 886–9, June 3, 1926. Unusual foundation conditions at site for diversion dam for Pit No. 3 power development of Pacific Gas and Electric Co., influenced adoption of concrete baffle piers in conjunction with lining of river channel for distance of 150 feet downstream to guard against possible scouring and erosion at toe of dam. A small concrete diversion dam on Rock Creek, the waters of which are diverted into Pit No. 3 tunnel, was constructed as 1/20 scale model of main structure and experiments were carried out to determine proper shape, sizes and location of piers. Main dam is an ogee spillway type concrete structure, 112 feet in height from foundation level to crest, with spillway section 18 feet deep and 267 feet long, designed to pass flood of 70,000 second-feet. Dam is arched in plan to radius of 500 feet. Concrete apron has minimum thickness of 4 feet and extends maximum distance of 150 feet downstream from toe of dam.—*R. E. Thompson.*

High Duty of St. Paul Cross-Compound Pumping Units. J. W. Kelsey. Eng. News-Rec., 96: 855, May 27, 1926. Brief description of unusual combination of 3 horizontal cross-compound pumping engines which comprise part of 5 year program of water works improvements just being completed at St. Paul, Minn. Water ends are identical, each having capacity of 15 m.g.d., but steam ends vary to provide for 3 different heads, 70, 175 and 220 feet. Extremely high duties were obtained in installation tests, approximate figures per 1000 pounds of steam, in millions of foot-pounds, being 160 for low-lift, and 182 for both intermediate and high-lifts. Boilers are horizontal water tube type, carrying 200 pounds gage steam pressure. Steam is delivered to engine throttle at about 100° superheat. Boilers are equipped with underfeed stokers and ashes are conveyed by vacuum system to hopper in bottom of smokestack, where they can be delivered through chute to truck. All auxiliaries are steam-operated, exhaust being employed to heat boiler feed in open feed-water heater. During 1925 all 3 pumps discharged 7670 m.g. by plunger displacement and 3.47 per cent less by venturi, which represents slip. Station duty in foot-pounds per B.t.u. was 80.7, and in foot-pounds per 100 pound of coal 106,944,000. Pumping cost was $7.70 per m.g., or 5 cents per foot head.—*R. E. Thompson.*

Boston To Go To Ware and Swift Rivers for More Water. Eng. News-Rec., 96: 934–5, June 10, 1926. After 7 years of agitation and engineering investigation, a bill for additional water supply has been passed by Massachusetts Legislature. Under terms of bill, special construction commission is created to: (1) divert flood flow of Ware River in excess of 85 m.g.d., into Wachusett reservoir through aqueduct or tunnel large enough to carry proposed supply from River; (2) acquire land and water rights on Swift River watershed for future development under plan to be prepared by commission and submitted to Legislature in January 1927; and (3) make plans and cost estimates and submit draft to legislature on filtration and chlorination of both Cochituate and Sudbury sources of supply (now used only in case of emergency owing to pollution). Act provides fund of $15,000,000 for carrying our construction, of which $14,000,000 will be derived from state bonds to be charged upon several towns and cities sharing metropolitan supply, and $1,000,000 from City of Worcester in relinquishing all rights in Nashua River above Wachusett reservoir, except for supply of 10 m.g.d. from Quinapoxet River.—*R. E. Thompson.*

New Collector for Sampling of Filter Sand. August V. Graf. Eng. News-Rec., 96: 868–9, 1926. Apparatus for sampling sand of mechanical filters designed by John Allgeyer is described which consists of 2-inch split and hinged brass pipe which is lowered vertically into sand bed during washing and withdrawn after wash water has been shut off and filter completely drained. —*R. E. Thompson* (*Courtesy Chem. Absts.*).

Laying 54-inch Main Across Mississippi River at Minneapolis. John A. Jensen. Eng. News-Rec., 96: 868, May 27, 1926. During 1924–5 Minneapolis Water Dept. laid new line of 50- and 54-inch pipe to connect new Fridley filtration plant with existing supply main. The 54-inch portion of line crosses Mississippi River at point where width is 600 feet and depth 4–7 feet. Pipe was of 2-inch riveted steel and was delivered in 30-foot lengths. In installing pipe in trench, front end was closed with torpedo cone head, and as succeeding sections were added it was pulled into river 30 feet to the pull. Length of crossing was 743.9 feet. Total labor cost was $7,650.26 or $10.28 per linear foot.—*R. E. Thompson.*

Flood Control Controversy in Los Angeles County. Eng. News-Rec., 96: 890–2, June 3, 1926. Data given regarding flood control controversy in Los Angeles County, California, in connection with which hearings have been recently held before committee of federal engineers. Several dams have been completed and Pacoima Dam, which is 375 feet in height, is under construction. There has been general objection to scheme of flood protection and to site chosen for proposed San Gabriel River Dam which, when completed, would be by far the highest dam in the world, rising approximately 500 feet above lowest part of foundation.—*R. E. Thompson.*

Device for Measuring Aggregates at the Concrete Mixer. Eng. News-Rec., 96: 1031, June 24, 1926. Brief illustrated description of device, which can be operated by mixer-man, for measuring 3 sizes of aggregate by volume simultaneously.—*R. E. Thompson.*

How Turbid Colorado River Water Was Made Fit to Drink. Irving C. Harris. Eng. News-Rec., 96: 896-7, 1926. The water supply of El Centro, Calif., is drawn from an irrigation canal carrying Colorado River water, which contains about 1 per cent by weight of sediment. The water flows through 8 settling reservoirs which provide retention period of 5–10 days, and is filtered through two 24 by 200-foot filters of 5 million gallons per day capacity at normal rate of 22.7 million gallons per acre per day. Other than chlorination of filter effluent, no chemical treatment is employed. The filters are cleaned with a traveling Blaisdell washer. Sedimentation removes approximately 90 per cent of bacteria from raw water and the filters about 90 per cent of those remaining. Aëration is desirable to reduce tastes due to vegetable growths in canals. Content of soluble salts averages 300-400 p.p.m. Cast-iron pipe is employed, as wrought-iron has very short life under existing soil conditions. All services are of lead and all are metered. Water rates are 16 cents per 1000 gallons for first 20,000 gallons with minimum charge of $2, which covers first 12,500 gallons used. All water used between 20,000 and 100,000 gallons is charged at 15 cents and all in excess of 100,000 at 14 cents per 100 gallons. Consumption is 1–2 m.g.d. and population 6–7000. Removal of silt from reservoirs is considerable item of expense. Several acres have been covered to depth of 20 feet or more and 10 acres of land have been purchased for future operations.—*R. E. Thompson (Courtesy Chem. Absts.).*

Weighted Canvas Controls Quicksand While Concete is Poured. R. J. Reigeluth. Eng. News-Rec., 96: 1033, June 24, 1926. During construction of tunnel within 10 feet of power house of Steel Power Plant of United Illuminating Company, Bridgeport, Conn., quicksand was encountered 18 feet below high water level. Excavation was carried out inside cofferdam with clamshell bucket, and when quicksand was struck the area was flooded and excavation continued by operating clamshell under water. Bottom was leveled with water jet and one section was covered with 25-ounce duck held in place by 500-pound precast concrete blocks. Concrete mat, 5 feet thick, was then deposited, and excavation was pumped dry after period of 21 days. —*R. E. Thompson.*

Correct Chart for Converting Kutter's "n" into Hazen and Williams' "c". R. de L. French and F. M. Wood. Eng. News-Rec., 96: 954-5, 1926. Chart given and method of use described briefly.—*R. E. Thompson (Courtesy Chem. Absts.).*

Low Leakage in 42-inch Submarine Pipe. Eng. News-Rec., 96: 909, June 3, 1926. Final test recently made by City of San Francisco on 404.6-foot length of 42-inch flexible cast-iron submarine pipe across Newark Slough showed leakage of only 9.7 gallons in 24 hours under water pressure of 170 pounds per square inch, almost all of which was accounted for at end flange connections used for test. Specified allowable leakage was 280 gallons per hour. One joint required recalking. Main Bay crossing, 2750 feet long, is also believed to be tight, within limits of specification.—*R. E. Thompson.*

Substitute Surface for Jet Condensers at Wart Station, Buffalo. S. E. Roof. Eng. News-Rec., **96**: 869-70, May 27, 1926. Surface condensers are being substituted for jet condensers in the five 30-m.g.d. vertical triple-expansion pumping engines at Buffalo. Specifications require 1800 square feet of cooling surface for each pump. Vacuum within 1 inch of barometer reading can be maintained without difficulty in two pumps completed.—*R. E. Thompson.*

Spray Hot Water to Cool for Domestic Use. Eng. News-Rec., **95**: 870-1, May 27, 1926. Water supply of Highland Park, suburb of Dallas, Tex., is obtained from 2 artesian wells 2865 feet deep. Temperature of water is 110°F., and until cooling system was installed in 1924 very little reduction in temperature occurred before water was delivered to consumer. Cooling system consists of spray nozzles through which water is sprayed 7 feet in air. This reduces temperature to average of 84° during night and 88° during day.—*R. E. Thompson.*

The Importance of the Uniform Distribution of Chlorine in Pool Waters of Bathhouses. G. Elkeles. Gesundheits-Ingenieur, **49**: 11, 151-153, March 13, 1926.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Absts.*).

Albany to Have $11,000,000 Water System. Health News (N. Y.), **3**: 163, October 11, 1926. Supply is to come from 3 practically uninhabited watersheds on the Hannacroix Basic basin by gravity. Storage dam at Alcove will impound 4 billion gallons and reservoir at Indian Fields will impound 8 billion gallons. Water will be stored six months, chlorinated, aerated, chlorinated a second time, and distributed. It is expected to supply 30 m.g.d. —*Jack J. Hinman, Jr.* (*Courtesy Chem. Absts.*).

Alleged Water Contamination Made Basis for Suit. Health News (N. Y.), **3**: 162, October 11, 1926. Three suits totalling $30,000 have been filed against city of Albany for alleged damages and breach of warranty. It is alleged that typhoid fever was contracted from the city water.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Absts.*).

Paper Mill Water Supply for Nekoos Edwards Paper Company, Port Edwards, Wisconsin. E. P. Gleason and C. F. Watson, Bull Assoc. State Eng. Soc., **1**: 55, 1926. Water for paper making should show practically no suspended matter and not more than 15 p.p.m. true color, 0.2 p.p.m. Mn, or 0.5 p.p.m. Fe. Water from Four Mile Creek containing 60 p.p m. color, 2.5-3.0 p.p.m. Fe and practically no Mn was found to be satisfactory if treated with 3 grains per gallon aluminium sulphate and given long sedimentation. A basin of 12 acres providing 48 hours sedimentation was constructed and found to yield a suitable water after treatment.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Absts.*).

Water Supply for Arlington County, Virginia. Clyde P. Ross. Mun. & County Eng., 70: 188–91, 1926. About one million gallons per day are required for Washington and Arlington districts which had a population of 12,372 in 1920. Two alternative plans are suggested; one to obtain the supply from about 50 widely distributed wells at depths of from 100 to 150 feet, and the other to build a purification plant and obtain the supply from a surface source at considerable distance.—*C. C. Ruchhoft.*

Graphical Chemistry in Water Softening. R. L. McNamee. Eng. & Cont., 65: 285–90, 1926. Charts for estimating soap requirements, temporary hardness, degree of hardness, lime and soda ash dosage, and molecular combinations are presented.—*C. C. Ruchhoft* (*Courtesy Chem. Absts.*).

Repairing Break in Aqueduct. James A. O'Connor. Eng. & Cont., 65: 415-6, 1926. Excavation for new concrete water conduit of Washington, D. C., which parallels old 9 foot brick aqueduct, caused break in the top half of section of latter. This was repaired with a rectangular reinforced concrete section.—*C. C. Ruchhoft.*

Measuring Water Levels in Wells. G. C. Habermeyer. Eng. & Cont., 65: 251, 1926. Apparatus for measuring water levels in wells is described. An insulated wire and, where lighting circuits are available a lamp, otherwise two dry cells and a buzzer, are used with apparatus containing a float which closes the circuit, for lowering into the well.—*C. C. Ruchhoft.*

Accounting Methods for Water Works. Harold D. Smith. Eng. & Cont., 65: 253–56, 1926. Necessity for accurate records and occasional audits to self-supporting water works system is discussed. Accounting procedure of high type, but not necessarily uniform, is essential. Customers deposits should be handled as a trust fund, separate and intact.—*C. C. Ruchhoft.*

Water Works Statistics. Anon. Pub. Wks., 57: 302-7, 1926. Statistics on meter rates and percentages of services metered, chemicals used in water purification, sizes of mains laid, and kinds of pipe used are tabulated for 200 cities.—*C. C. Ruchhoft.*

City Authorities Held Responsible for Typhoid: Anon. Pub. Wks., 50: 697-8, 1926. In test case, court found officials negligent and awarded damages for illness during typhoid epidemic at Owen Sound, Ont.—*C. C. Ruchhoft.*

Some Small Water Purification Plants. W. A. Hardenbergh and K. W. Grimley. Pub. Wks., 57: 275–279, 1926. Well and surface waters of eighteen of the thirty-five plants in Jefferson County, Alabama, serving more than fifty persons receive some treatment. Details of several small filter and chlorination plants are given.—*C. C. Ruchhoft.*

New Walton Filters of London, England. Anon. Eng. & Cont., 65: 417–21, 1926. General layout and construction details are given. The primary filter plant has 18 open rapid rate filters with total capacity of from 18 to 36 m.g.d. Water is admitted to filter beds at maximum head of 10 feet. Filter bed has 18 inches of graded gravel and 30 inches of sand. Filtered water collection pipes are connected with compressed air and wash water systems, air being blown through to loosen sand before washing filter. From primary filters, water flows through covered clear water channel to secondary filter beds, of which there are six, with an area of $\frac{5}{8}$ acre each. There is a chlorinating and recorder house for each group of 3 filters. Sand of the secondary filters is removed for washing partly by manual labor and partly hydraulically. Washing is done in hoppers arranged in trains of four, each on a small truck. Sand thus receives four successive washings and is returned to the filter for spreading in workable layer.—*C. C. Ruchhoft.*

ABSTRACTS, SUBCOMMITTEE NO. 9

Joint Research Committee on Boiler Feedwater Studies

Boiler Water Conditioning with Special Reference to High Operating Pressure and Corrosion. R. E. Hall. Combustion, 15: 3, Sept. 1926, pp. 156–159, 1 fig. Scope of boiler-water conditioning; prevention of scale formation on evaporating surfaces; relation between chemical used in treatment and operating pressure; control of non-condensable gases in steam by conditioning of boiler water.

The Treatment of Boiler Feedwater by Means of Evaporators (Die Aufbereitung des Speisewassers für Dampfkessel mittels Verdampferanlagen). Wintermeyer. Feuerungstechnik, 14: 22, Aug. 15, 1926, pp. 263-266, 2 figs. Disadvantages of chemical treatment; degassing of feedwater; preparation of feedwater by evaporation, whereby condensate and distillate are precipitated as feedwater; examples of modern evaporator plants; cooling-water evaporators.

Water and Its Impurities. J. C. Moore. Power House, 20: 17, Sept. 5, 1926, pp. 17–19. Effect of impurities in feedwater of boilers is to cause deposition of scale on interior of water-heating surfaces, in addition to deposition of mud or sediment, thus facilitating corrosion and foaming; corrosion results mainly from use of hard water; causes of hard water; how deposit becomes hard; carbonates of magnesia; alkalinity of water; test for calcium salts; treatment to prevent scale; water filtration.

Preheating Pump. E. Josse. Eng. Progress, 7: 8, Aug. 1926, pp. 208–209, 3 figs. Details of pump manufactured by firm of F. Seiffert and Co., Berlin, novel feature of which is that boiler feedwater is heated inside pump in direct contact with bleeder steam, pump raising pressure of condensate of prime movers fed back to boilers, from condenser pressure to boiler pressure.

Concentration of Caustic Soda in Connection with Boiler Plate (Laugenkonzentrationen in Verbindungen von Kesselblechen). R. Baumann. Archiv für Wärmewirtschaft u. Dampfkesselwesen, 7: 9, Sept. 1926, pp. 255-260, 16 figs. Results of investigation carried out for German Union of Boiler Users, showing that supposed concentration of salts, especially of caustic soda, in rivet seams is only possible if seams are leaking and feedwater is very salty.

Boiler Corrosion on the Canadian Pacific Railway. T. W. Lowe. Boiler Maker, 26: 8, Aug. 1926, pp. 223–226. Report on Paper entitled "Boiler Fitting and Corrosion," presented at Master Boiler Makers' Assn.

The Problem of Steam-Boiler Corrosion. F. N. Speller. Mech. Engrg., 48: 10, Oct. 1926, pp. 1017–1023, 2 figs. Mechanism of corrosion; boiler feedwater; dissolved oxygen and CO_2; salt, alkali and acid content; influence of scale, organic matter, and composition of materials of construction; preventive measures; general precautions for care of boilers.

Investigation of Strongly Corroded Brass Condenser Tubes (Untersuchungen von Messingkondensatorrohren mit starker Korrosion). M. Schwarz. Korrosion u. Metallschutz, 2: 1, Jan. 1926, pp. 8–17, 17 figs. Examination of tubes from two power plants showed basic zinc carbonate in corroded spots and experiments showed that cooling water attacked beta mixed crystals of brass.

Pitting of Locomotive Boilers. W. A. Pownall. Ry. Rev., 79: 8, Aug. 21, 1926, pp. 263–270, 5 figs. Observations of boiler corrosion in various forms.

High-Pressure Filtration of Softened Water. L. H. Biggar. Power Plant Eng., 30: 19, Oct. 1, 1926, pp. 1050–1051, 1 fig. High head, fine clean sand bed of low uniformity and high porosity and removal of deposited solids give clear filtered water.

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PRETREATMENT OF BOILER FEEDWATER

Progress Report of Sub-Committee No. 2 on Water Softening by Chemicals (External Treatment)[1]

By Clarence R. Knowles, *Chairman*

The following subjects were assigned to Sub-Committee No. 2 for investigation and report:

1. The chemical reactions to be considered in the light of present knowledge of physical chemistry, with special attention to the hydrogen-ion concentration of water and its influence upon the precipitation of hardening salts.
2. Compilation of operating data to determine the relative value of continuous and intermittent softeners.
3. Collection of operating figures showing the efficiency of subsidence tanks and basins in order to be able to submit recommendations for the more efficient design of basins for precipitation of solids and the removal of sludge.
4. The causes and prevention of retarded chemical reaction.
5. Standardization of rates of filtration employed for the removal of suspended solids from softened water.

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[1] The personnel of Sub-Committee No. 2, on Water Softening by Chemicals (External Treatment), of the Joint Research Committee on Boiler-Feedwater Studies is as follows:

Clarence R. Knowles, *Chairman*, Superintendent of Water Service, Illinois Central Railroad, 135 East 11th Place, Chicago, Ill.

A. M. Buswell, Director, Water Survey, Urbana, Ill.

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C. P. Hoover, Chemist and Superintendent, Water and Sewage Department. Columbus Filter Plant, Columbus, Ohio.

C. P. Van Gundy, Superintendent, Water Service, Baltimore and Ohio Railroad, Baltimore, Md.

Joseph D. Yoder, Charge of Water Purification Department, H. S. B. W.-Cochrane Corporation, 3107 North 17th Street, Philadelphia, Pa.

6. The effect of siliceous material as a filtering material when used in conjunction with hot chemical softeners, and the value of non-siliceous filtering material.

7. A consideration of the economic value of lime-soda softener treatment preliminary to zeolite softeners or to evaporators.

8. Standardization of nomenclature employed in the field of softening of water by chemicals and of the apparatus and appurtenances in use in these systems.

Your Committee presents reports on the above subjects as follows:

Study A: Report on the relative value of continuous and intermittent water softeners.

Study B: Report on the economic value of lime-soda softening preliminary to zeolite softening.

Study C: Report on the economic value of lime-soda softening preliminary to evaporators.

STUDY A. OPERATION OF CONTINUOUS AND INTERMITTENT LIME-SODA WATER-SOFTENING PLANTS

The investigation of this subject has necessarily been broadened somewhat to include a study of the typical equipment employed in each type of softening plant, in view of the intimate relation existing between the installation and operation in both cases. As any manufacturer of water-purification equipment may build either the continuous or intermittent type of apparatus, subject only to the limitations of his technical knowledge and engineering skill, it was felt that an impartial study of this important angle of the problem could be made.

A typical continuous softener, as its name implies, provides for the continuous treatment, settling, and filtration of a water at either a constant or variable rate of flow through the apparatus. Ordinarily the retention period provided is four hours, with the softener running at its full rated capacity, although in some cases this has been decreased slightly and in others has been materially increased.

The typical intermittent softening plant comprises two or more tanks which are filled, treated, and emptied by the batch method, together of course with the necessary auxiliary equipment. In this case, also, the minimum time for which each tank is in service is 4 hours; but in this case a half-hour is provided for filling the tank, a minimum of 2½ hours for settling, and 1 hour for emptying. The service period of each tank and the number of tanks are frequently increased.

Comparison of Equipment

Size of reaction and settling tank. The typical intermittent plant requires a total tankage of at least 50 per cent more than the continuous plant, and usually requires at least twice as much floor space.

Storage. Since a tank of the intermittent plant must be emptied rapidly, in order not to waste the settling capacity of the tank, provision is generally made to accomplish this emptying in not more than an hour. The treated water is discharged through filters into a clear-well with a capacity usually equal to one and one-half to two hours normal water consumption, or more.

Obviously the continuous softening plant does not require storage of this sort, since it is delivering treated and filtered water uninterruptedly and can meet the demand as it occurs.

Filters. Assuming that an intermittent tank holds a four-hour supply of water and is emptied in one hour, it is obvious that considerably greater filter capacity must be provided than for the continuous softener in which the same total quantity of water is distributed over a four-hour period.

Pumps. If pumping of the raw-water supply to the softener is necessary, the intermittent plant will require pumps with about four times the capacity of those needed for the continuous plant, since the volume of water pumped into one of the intermittent tanks in an hour is distributed in the case of the continuous plant over a four-hour period. Much of this head is lost in the case of the intermittent plant due to the decreasing head as the tank is drained. In the continuous plant, with a draw-off of the treated water at the top of the tank, the head is retained in large measure.

Mixing chemicals with water being softened. In the continuous type of apparatus, where a relatively small amount of water is being treated at any given moment, it is not particularly difficult to secure good mixing of the chemicals with the waters being softened. In the intermittent system, in which the entire tank supply is treated at once, special provision must be made for the distribution of the chemical reagents throughout the large mass of water being treated. In small plants mechanical stirrers may be employed. In larger plants, compressed air is usually the agent employed for agitation, a compressor and auxiliaries thus becoming an essential unit in this type of plant.

Initial cost. The initial cost of an intermittent plant, installed, of reasonably large size, to meet the requirements of boiler-feed-water purification, will average from about 30 to 50 per cent more than for a continuous plant of the same hourly capacity. The difference in the overhead expense of the two plants thus becomes an item of importance in considering the operation of the apparatus.

Comparison of operation

Cost of chemicals. The amount of chemicals required in either case is approximately the same. It is standard practice in the case of the intermittent plant to employ a coagulant, usually sulphate of iron, in addition to the lime and soda required for treatment. The use of a coagulant is not standard practice with all continuous plants, but the evidence in many cases indicates that the improvement in results of the water treatment in such cases effected by the use of a coagulant is sufficient justification for the additional expense.

Cost of power for operation. The total cost of the power necessary for operating these plants is not vastly different for the two types, except in special cases in which the larger pumping cost for the intermittent plant may amount to a considerable item of expense.

Cost of labor. In very large plants, say, 50,000 gallons per hour or more, the amount of labor required for the two types of plants is approximately the same, since in both cases the entire time of one man is usually devoted to the care and operation of the plant. In smaller plants, however, there is a marked difference in the amount of labor required. For plants ranging from those of very small size up to about 20,000 gallons per hour, the total time required in the case of the continuous softener should not exceed about 3 hours; while in the case of the intermittent plant, practically the entire time of one man will be required.

This difference in the amount of labor involved is due, of course, to the fact that in the case of the continuous softener the chemical feeding tanks may be filled very quickly with enough of the reagents to treat water for a good many hours' supply; or in the case of the intermittent softener the succession of filling, treating, and emptying operation is necessarily so frequent that a man's time is pretty well occupied.

Comparison of results obtained

Assuming proper operation in both cases, properly treated water can be obtained from either type of apparatus. The particular field of usefulness of the intermittent type of softener has been held to be for waters of variable composition, such as those of rivers and of other sources of supply. The validity of this statement is not evident upon a careful examination of the method of operation of a typical intermittent softener, nor of the results obtained. The ideal way to handle water in an intermittent softener, of course, is to take a sample of the water shortly after it has been thoroughly mixed with chemicals, and from tests on this water determine what change, if any, is necessary in the treatment. If a change is found necessary, which could easily be the case with a water of changing composition, the tank of water would have to be held until the treatment was adjusted either by the addition and agitation of more chemicals, or by the waste of treated water to allow for dilution with enough raw water to compensate for the overtreatment. The loss of time involved here would so lessen the effective period of service of a tank that the number of tanks would have to be increased to provide for such contingencies. Observation of the actual operation of intermittent plants shows that as rule the charge of one tank is based upon the chemical test made on the water of the previously treated tank; that is, the treatment of any particular tank is at least one tank behind any change in composition of the water.

In general, the human element would seem to play a greater part in the operation of an intermittent softener than in a continuous plant, since the number of man-made operations is considerably greater during the course of a day's operation.

STUDY B. ECONOMIC VALUE OF LIME-SODA SOFTENING PRELIMINARY TO ZEOLITE SOFTENERS

The economic value of lime-soda softening preliminary to zeolite softening is dependent upon so many conditions that perhaps the best that any committee can do for the guidance of the general public in this respect is to point out the conditions which will affect the economic value of preliminary treatment so that these points will be given consideration when this question is decided.

Such preliminary treatment as the water requires for filtration purposes may be disregarded, for it is assumed that it is well understood that all waters containing suspended matter must be satisfactorily filtered before delivery to a zeolite softener. Whether or not sedimentation must be provided ahead of the filters is purely a filtration problem. The water must be made crystal clear before delivery to a zeolite softener.

Consideration must be given to the following:

1. *Direct use to which softened water will be applied.* If the softened water is to be delivered to evaporators the presence of a large amount of sodium carbonate will not necessarily be seriously objectionable. Likewise, the sodium carbonate is not objectionable if required to soften the make-up water of the circulating system when using a cooling pond, to prevent scale formation on the tubes of surface condensers.

Where zeolite-softened water is fed directly to the boilers the high sodium carbonate resulting from this treatment is objectionable for the following reasons:

a. There is a tendency to cause foaming and priming of boilers because of high alkalinity concentrations in the boiler. To prevent priming the boilers must be blown down sufficiently, the amount of water depending upon the type of boilers, the rate at which boilers are fired, and other operating conditions.

The question in this respect that must be considered is "How much less will the boilers need to be blown down to prevent priming if the water is given preliminary softening before zeolite softening than if the zeolite softener is used alone?" Clearly the blow-down losses for boilers operated at high ratings will exceed the losses for comparatively small boiler plants where customarily boilers are not much overloaded. For small boiler plants unquestionably zeolite softeners have been used with satisfaction without pretreatment, whereas for larger plants with boilers operated at considerable overload pretreatment would be necessary before zeolite softening.

b. The probable effect of the sodium carbonate on caustic embrittlement of boiler plate is not well understood. The May, 1925, issue of *Mechanical Engineering* gave the suggested rules for care of power boilers which contained the recommendation that for working pressures of 150 pounds and under the alkalinity in terms of sodium carbonate should not exceed the sodium sulphate; for working pressures over 150 pounds and under 250 pounds alkalinity not to exceed one-half the sodium sulphate; for working pressures of 250 pounds and higher, alkalinity not to exceed one-third the sodium sulphate.

Many water treated by zeolite softeners will give a ratio of sodium carbonate to sodium sulphate unfavorable to the above recommendations of the A. S. M. E. Boiler Code Committee. To determine the economic value of pretreatment from the standpoint of embrittlement it is not only sufficient to give consideration to the amount of temporary hardness in the raw water, but the amount of sulphates present must also receive consideration. This will, furthermore, obviously be dependent upon the boiler pressure. The higher the boiler pressure the more necessary the pretreatment for a given water supply.

The after-treatment of a zeolite-softened water with sulphuric and phosphoric acid is now being done in a number of commercial plants to lower its alkalinity.

2. Cost of pretreatment. The cost for additional equipment for pretreatment is considerably greater per thousand gallons of water treated for small capacities than large. Consequently, it would follow that pretreatment might prove economical for comparatively large installations, whereas it might not be economical for small capacities. The comparative costs must therefore be considered.

Again, it is obvious that the additional cost of equipment for pretreatment to lower the carbonate hardness will be considerably less if in any event the water requires filtration. Particularly is this true if the water requires sedimentation ahead of the filters. If before delivering water to the zeolite softener the water must be filtered and also settled, the additional cost for pretreatment of the water for lowering the hardness will be much less than if a city supply of well water, that does not require filtration, were available.

The cost of chemicals for removal of the temporary hardness is ordinarily less than the cost of salt, considering that for calcium carbonate hardness more than 4 pounds of salt must be used for the equivalent accomplished by 1 pound of hydrated lime, for precipitation of magnesium carbonate 2 pounds of salt are required for the equivalent of 1 pound of hydrated lime. The costs of salt and lime vary quite considerably depending upon the proximity to the source of salt and hydrated lime. Freight rates have an important bearing on these costs.

Comparative cost of pretreatment must also be considered with an after-treatment of a zeolite-softened water with sulphuric and phosphoric acid which is now being done in a number of commercial plants to lower the alkalinity of zeolite-softened water.

This question must also be considered in comparison with the cost of equipment for softening the water without introducing large amounts of sodium carbonate as may be obtained by hot process and cold-process lime and soda softeners.

From a study of the above it is evident that the question of whether or not pretreatment is advisable becomes complicated if an attempt is made to derive a formula applicable to all conditions whereas a consideration of all the above factors generally becomes very simple for any plant if all the conditions are known. It is therefore believed that the best that this Committee can do is to point out the influencing factors, the most important of which have been mentioned above.

STUDY C. ECONOMIC VALUE OF LIME-SODA SOFTENING PRELIMINARY TO EVAPORATORS

The economic value of lime-soda softening preliminary to evaporators is dependent upon so many conditions that a number of the recommendations made for pretreatment to zeolite softeners in our previous report will be applicable to pretreatment for evaporators.

A survey of the central stations using evaporators indicates that waters containing 10 grains or more "total hardness" are being given pretreatment, and that waters containing 6 and 7 grains total hardness are being evaporated without apparently giving serious trouble.

A total of 55 questionnaires was sent out to central stations throughout the country, using evaporators, requesting data relative to operating conditions, cleaning, nature of water, etc. The results of this survey are classified as follows:

Class 1. Eighteen questionnaires have not been acknowledged (32.7 per cent). A second attempt was made to obtain data from these companies, but apparently without success. The possible explanation for this may be that questionnaires were addressed to holding companies as well as to the individual company.

Class 2. Thirteen users acknowledged the questionnaire, but for various reasons have not furnished information (23.6 per cent). These were returned not filled out for various reasons: equipment not yet in service; equipment in stand-by plants; equipment not been in service long enough to accumulate data; no available data, etc.

Class 3. Twenty-four users returned the questionnaire filled out as requested (43.7 per cent). These questionnaires containing the requested data have been carefully analyzed, and from this information our report has been prepared.

The analysis of the questionnaires indicates that 42 per cent of the users regard pretreatment warranted on account of scale, but 58 per cent of the users regard pretreatment not warranted. Of the 42 per cent who regard pretreatment warranted, 21 per cent use external softeners, 12.6 per cent use internal treatment, but do not regard it satisfactory, and 8.4 per cent give no treatment, but recommend it.

A careful examination of the chemical analysis of the waters used by the above installations indicates that with the exception of one water all have a "total hardness" of 10 grains or higher. The one exception has a "total hardness" of only 6 grains. Of the 58 per cent who regard pretreatment *not* warranted, 53.9 per cent use water less than 6 grains "total hardness," and 4.1 per cent use water of 7 grains "total hardness."

One installation of the above 58 per cent treats the water with sulphuric acid to give a more favorable relation of sodium sulphate to sodium carbonate on account of water naturally containing 6 grains of sodium carbonate per gallon. This is done because the evaporator gives off some moisture, and soluble salts are formed in the distillate.

It would be a difficult matter to try to indicate the average saving in dollars and cents to be obtained by pretreatment ahead of evaporators as there are so many variables to be considered, i.e., the amount of water evaporated between cleanings; the condition of the water; irregular cleaning periods ranging from one week to one year; reduction in capacity varying from 2 to 50 per cent, and cost of cleaning varying from $20 to $600.

The cost of additional equipment for pretreatment might be considerably greater per thousand gallons of water treated for small capacities than for large capacities; consequently it would follow that pretreatment would prove economical for comparatively large installations, whereas it would not be economical for small capacities.

The most significant facts brought out by this investigation are that waters containing 10 grains or more "total hardness" are being given pretreatment, and that waters containing 6 and 7 grains "total hardness" are being evaporated without apparently giving serious trouble.

In conclusion, we wish to thank the central stations for the generous manner in which they furnished us with the information requested.

PRESENT KNOWLEDGE OF FOAMING AND PRIMING OF BOILER WATER, WITH SUGGESTIONS FOR RESEARCH

Progress Report of Sub-Committee No. 3 on Zeolite Softeners, Internal Treatment, Priming and Foaming, and Electrolytic Scale Prevention[1]

By C. W. Foulk, *Chairman*

In 1893 Stromeyer[2] in his work on marine boilers wrote that information on the subject of priming was "almost non-existent." Eighteen years later Stabler[3] evidently felt that little information had been added, for he began his section on foaming and priming with the statement that they "are probably the least understood of boiler phenomena." At the present day, sixteen years later, Stabler's statement still holds. The only modification that suggests itself would be to leave out the word "probably."

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[1] The personnel of Sub-Committee No. 3 on Zeolite Softeners, Internal Treatment, Priming and Foaming, and Electrolytic Scale Prevention, of the Joint Research Committee on Boiler-Feedwater Studies is as follows:

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[2] C. E. Stromeyer, Marine Boilers, p. 42 (1893).

[3] Herman Stabler, Eng. News, vol. 60 (1908), p. 355 and U. S. Geological Survey, Water Supply Paper 274, p. 171 (1911).

PHENOMENA TO WHICH THE NAMES "FOAMING" AND "PRIMING" HAVE BEEN APPLIED

Much effort has been expended in the past in trying to define "priming" and "foaming." A search of the literature shows utter confusion in the use of these terms. Some authors employ them interchangeably. Some call a foam on the surface "priming," and others call violent ebullition "foaming." Indeed, it can be said that a reader of any book or paper will not know what is meant unless the writer defines his terms.

Fortunately the question can be approached another way. Instead of seeking the meaning of the terms one can differentiate and describe the phenomena to which these various names have been applied. From this standpoint, then, an examination of boiler-water papers shows that one or more of three fairly distinct mental pictures of phenomena inside the boiler were in the minds of writers when they used the terms "foaming" and "priming:"

1. The formation of foam on the surface of the water. This foam may range in thickness from a layer barely covering the surface to a mass that fills the steam space above the water. In the latter case the liquid films around the bubbles would be drawn into the steam pipe and wet steam would result.

2. Another phenomenon evidently in the minds of certain writers is merely rapid ebullition with the consequent projection of droplets or even slugs of water into the steam pipe. This could happen without the appearance of foam as it is described above.

3. A third situation partakes both of the properties and appearance of foam and of violent ebullition. The boiling is of such a character that the whole mass of water from the bottom up is full of fine steam bubbles, with the consequence that the interior of the boiler is filled and of course much water passes out with the steam.

It should be emphasized, perhaps, that the three situations pictured above are not necessarily descriptions based upon actual observations of steam boilers in operation. If such observations have been made the author has failed to find the record of them. They are to be looked upon more as reasonable suppositions by men of experience with steam boilers, and who have undoubtedly observed analogous situations in glass flasks or open metal vessels. Moreover, some writers evidently have no picture in mind of what goes on inside the boiler. They simply use the terms as meaning any entrainment of water by the steam.

Systematic research may show that a fourth phenomenon, namely, the manner in which bubbles break on the surface of the water in the boiler, should also be considered, at least as one of the causes of wet steam. This idea was first suggested to the author by Dr. R. E. Hall, who used the phrase "smoothness of boiling."

It is well known that a bubble breaking on the surface of a liquid projects a droplet of the liquid to a height of several inches. This phenomenon has never been studied so that nothing is known of its mechanism or of any way of controlling it. It seems reasonable to suppose that a continual projection of droplets of water into the steam space would be a large factor—perhaps the determining factor—in causing wet steam when other conditions were normal, that is, when there was no foaming or priming.

The confusion of terms that exists is deplorable, and now that an official committee[4] representing a number of interested engineering societies is at work on this feature of boiler-water behavior, one of its first duties should be the clarification of the nomenclature. However, before permanent definitions are formulated there should be an extensive series of accurate observations made, if possible, on actual steam boilers, and failing that, on experimental boilers, in order to determine with some precision the various causes for the entry of water from the boiler into the steam. Appropriate names can then be found for the phenomena.

CAUSES OF FOAMING AND PRIMING

Physical. The causes of foaming and priming as given in boiler-water papers fall under two general heads, physical and chemical. Among the physical causes the design and operation of the boiler are outstanding. The more complex the interior—that is, the more of a maze of tubes, staybolts, etc., there is in the boiler—the more likely is it to foam (prime). It is also evident that, other conditions being the same, the smaller the steam space above the water, the more likely is water to be carried out. If the boiler is moved about rapidly while in use, as is the case with railroad and marine boilers, the extra agitation will promote foaming.

Violent ebullition for a few seconds may result from the sudden evolution of steam following a period of superheating of the water analogous to the familiar "bumping" of liquids in the laboratory.

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[4] Jour. Amer. Water Works Assoc., vol. 13 (1925), p. 336.

A similar effect would be produced by the loosening of a sheet of scale, which would thus bring water into contact with almost red-hot metal. The sudden introduction of solid matter, entering with the feedwater or produced by the loosening of scale, also causes a violent ebullition for a few seconds, and a rapid opening of the steam valve by causing a momentary lowering of the pressure has the same effect.

There is some difference of opinion as to the relation of steam pressure to foaming, but the majority seem to hold that high-pressure boilers foam less than low-pressure ones. Such a statement seems logical because a given weight of steam occupies less space the higher the pressure it is under.

Chemical. The available information about the chemical causes of foaming may be classified inder (1) substances that cause foaming, and (2) physico-chemical explanations of the phenomenon. The offending substances are listed under such indefinite terms as "organic matter," "impurities," "oily matter," "soap and soapy substances," "saline matter, " "alkalis," and "suspended solids." Sodium salts seem to be the only definite chemical substances to which foaming and priming are generally attributed, but the author has not been able to find a record of any experiments which show that sodium salts alone are the cause of the trouble. The belief has unquestionably originated from the fact that in the great majority of waters sodium salts are the only ones that concentrate in the boiler. Others that are present in any quantity, such as calcium and magnesium compounds, precipitate for the most part.

Next to sodium salts finely divided solid matter is held responsible for foaming and priming, and some go so far as to assert that solids are the only cause, barring, of course, occasional cases of soap or peculiar forms of organic matter in the water. Here again, however, the record of experimental evidence in favor of this view is lacking.

In 1924 the author[5] acting on a hint from Bancroft[6] succeeded in harmonizing the conflicting statements concerning the effect of sodium salts and solid matter. An extensive series of laboratory experiments showed that sodium salts alone or finely divided solids alone did not cause a true foam, but that when both were in the water in sufficient concentration foaming resulted; that is, a true foam or froth several inches thick was produced on the surface of the water. The explanation of this is given below.

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[5] C. W. Foulk, Ind. & Eng. Chem., vol 16 (1924), p. 1121.

[6] Applied Colloid Chemistry, General Theory, p. 268. McGraw-Hill Book Co., N. Y. (1921).

THE PHYSICO-CHEMICAL THEORY OF FOAMING

Wherever the word "foam" or one of its derivatives is used in this section, it refers to a true froth or foam as described in No. 1 above.

It must be said at the start that there is as yet no comprehensive physico-chemical theory of foams. This fact, perhaps more than any other, retards the progress of research in this field. The statement frequently found that foaming is caused by lowering the surface tension of a liquid seems merely to express a coincidence. While it is true that the foamiest liquids (for example, soap and saponin solutions) have low surface tensions, it is also true that pronounced foaming can be produced by conditions that raise the surface tension. Water solutions of inorganic substances—sodium salts, for example—foam readily if the films are estabilized by finely divided solid matter. (See below.)

Furthermore there is no quantitative relation between the lowering or raising of the surface tension of a liquid and the foam producing power of the resulting solution. Water solutions of soap and saponin, for instance, may be equally foamy, the saponin even foamier than the soap, and yet the surface tension of the saponin solution will be much higher than that of the soap.

This question of the lack of relation between surface tension and foaming is discussed at length by Wo. Ostwald and A. Steiner,[7] who give many literature citations. The immediate relation of the problem to boiler water is touched upon by Millard and Mattson,[8] who show that what they call "priming" is in no way related to surface tension. Though these investigators do not distinguish between true foam and other phenomena, the description of some of their experiments leads one to think that foam should have been present.

About all that can be said is that pure liquids do not foam.[9] Something must be present of such a nature that its concentration in the surface differs from that in the mass of the liquid. This interesting situation is quite common and can be shown by laboratory experiments. If, for example, a mass of soap bubbles is collapsed the resulting liquid will be found to contain more soap per unit volume than did the original solution from which the bubbles were produced. Whether there is more or less of the added substance in the surface than in the interior of the liquid seems to make no difference. Either way, the surface layer differs from the rest of the liquid and thus makes possible a separation of films from the surface. This separation of films is the necessary condition for the formation of foams. There is, however, another condition which, if not theoretically necessary is practically so, namely, the stabilization of the films. Most bubbles burst in the moment of their formation and therefore cannot form a foam. The films of a true foam must have a certain structural strength and period of existence. This is given by the viscosity of the film itself, as in the case of soap bubbles, or by the addition of finely divided solid matter which imparts the necessary viscosity, as in the case of the foams of sodium salt solutions stabilized by pulverized boiler scale. (See below.)

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[7] Kolloid-Zeitschrift, vol. 36 (1925), p. 342.

[8] E. B. Millard and T. E. Mattson, Ind. & Eng. Chem., vol. 17 (1925), p. 685.

[9] Freundlich, Kappillarchemie, 2nd Ed., p. 1091 (1922).

No one has yet offered a plausible explanation of why a pure liquid does not foam and why a difference in concentration between surface and interior of a solution permits the separation of films. When a bubble generated in the interior of certain solutions rises to the surface it lifts a film; or when a ring composed of any solid that is wet by the liquid is applied with appropriate technique to the surface and lifted, a film is removed. What now determines the plane of separation of that film from the remainder of the liquid? The answer to that question would be the general theory of foaming.

The author believes that research on this fundamental problem should be directed to a study of the conditions which control the maximum *thickness* of films. Heretofore attention has been focused on their minimum *thinness*. Bancroft[10] who is an omnivorous reader, says, "I have not been able to find any statement as to the maximum thickness of a soap-bubble film; but it is certainly not less than 1.4μ." This is many hundred times as thick as the layers of oriented molecules pictured to account for surface-tension phenomena. In general, it would be well to direct research to the relatively thick (1.0 ± mm.) layer at the surface of liquids. It is the seat of peculiar phenomena. Liebreich called it the "dead space in chemical reactions" because certain reactions at least fail to take place in it. Hannan[11] refers to another phenomenon peculiar to this region, namely, the very rapid rate of sedimentation in it.

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[10] Applied Colloid Chemistry. General Theory, Second Edition, p. 456. McGraw-Hill Book Co., N. Y. (1926).

The relation of surface concentration to surface tension is in the sense that those substances which concentrate in the surface lower the surface tension, and those which recede from the surface increase the surface tension. It can also be shown both theoretically and practically that surface tension can be lowered to a much greater extent than it can be raised.

In general, organic substances lower the surface tension and inorganic ones raise it. There are, however, exceptions to this rule. Cane sugar, for example, slightly increases the surface tension of water and hydrochloric acid slightly lowers it.

APPLICATION OF THEORY TO BOILER WATER

On applying these principles to boiler water, it can be said that the fundamental condition of foaming is the presence of substances which concentrate either in the surface or in the mass of the water. If, however, these substances do not at the same time have the property of making the films around the bubbles stable, there will be no foam in a practical sense, because the life of the bubbles will be too short—they will burst a moment after forming. It is necessary, then, to distinguish carefully between the two conditions for the formation of foam—(1) the presence of something which, by modifying the surface of the water, makes possible the formation of bubbles, and (2) the presence of something which by imparting viscosity to the films will stabilize them—that is, prevent them from bursting immediately after forming. This necessary viscosity can, of course, be produced by the same substance which changes the surface. Soap, for example, is such a substance, and an occasional water is found in which the organic matter present has this property, either as it enters the boiler or after modification by the action of the superheated water. In the average boiler water, however, the change in the surface is brought about by dissolved sodium salts and the stabilization of the foam by finely divided solid matter. The presence of either one without the other is not sufficient to cause foaming.

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[11] Frank Hannan, Jour. Amer. Water Works Assoc., vol. 10 (1923), p. 1035.

The action of the particles of solid in stabilizing the foam appears to be purely mechanical. Edser,[12] in a paper on ore flotation, pictures the situation as follows:

> Imagine a number of bubbles in the interior of a liquid, each bubble being coated with mineral particles. When these coated bubbles come into contact after rising through the liquid, the walls of each cell will consist of numerous solid particles held together by films of liquid.

In flotation the solid particles are frequently the only stabilizing agent present. It must, of course, be emphasized that to stabilize a boiler-water foam as well as that of a flotation process the solids must have the property of adhering to (being adsorbed on) the films. Flotation as a method of separation would be impossible if solids did not behave differently in this respect and, it might be added, boiler foaming would be a rare occurrence were it not for the unfortunate circumstance that the solids usually present in a boiler have the property of adhering to the films around the steam bubbles.

Whether there is a manifest difference in the stabilizing effects of the different types of boiler scale has not yet been determined. Work now in progress in the author's laboratory suggests at least that this point should be investigated.

Other things being equal, the stabilizing effect increases as the size of the solid particles decreases. It is interesting, however, to note that particles so large that none will pass through a forty-mesh sieve can be seen adhering to the steam bubbles.

Koyl[13] gives the presence of finely divided solids as the cause of the phenomenon described above under (3), but merely states that each particle becomes a nucleus from which a stream of steam bubbles rises. It would not be too far-fetched to assume that the particles that act in this way have entrained minute bubbles of air, or perhaps of carbon dioxide, which would then serve as permanent gas-phase surfaces at which steam bubbles would form. The stabilizing effect of the finely divided solid matter would tend to hold such steam bubbles intact—that is, prevent them from coalescing. In this way

[12] Edwin Edser. Fourth Report on Colloid Chemistry, and Its General and Industrial Applications, British Association for the Advancement of Science, p. 263.

[13] Railroad Gazette, vol. 32 (1900), p. 663.

the mass of the water would become filled with bubbles, as Koyl describes.

In the author's previously mentioned paper a large number of laboratory experiments in glass flasks are described. This experimental evidence is too long to reproduce here, but is referred to because it furnished the confirmation of the theories advanced and which are given above. There is also another reason for referring to it. Ordinarily, laboratory experiments offer an unsafe guide for large-scale industrial operations, so that it is worth while in this case to record that the author has received additional evidence in the shape of a number of letters from persons of practical experience with steam boilers. These letters uniformly uphold the general conclusions of the paper, so that, in a way at least, it can be said that these laboratory experiments have been confirmed in practice.

ORGANIC MATTER AS A CAUSE OF FOAMING

Practically nothing is recorded concerning causes of foaming other than those mentioned above. The author has received two private communications to the effect that excelsior used as a filter in a water softener caused foaming during the first few days it was in use, after which the effect disappeared. This would mean of course that the water dissolved out certain organic materials that caused the trouble. Another communication cited the organic matter in certain of the highly colored surface waters of Florida as a cause of foaming. It would be interesting to know whether such colored waters from other parts of the country have the same effect, for example, those from New England. The question of the behavior of these waters, if at the same time they contain sodium salts and finely divided solids, is one that has not yet been studied.

TESTING WATER TO DETERMINE WHETHER IT WILL FOAM

A practical question naturally arises, namely, what chemical or physical tests can be made on a boiler water in order to determine whether it will foam? This point has never been thoroughly studied. Boiler-water chemists would determine the sodium-salt concentration and base their conclusions on the result. Stabler (footnote 3) in his famous paper giving equations by which the behavior of a water can be calculated, includes one on foaming which gives what he calls the "foaming coefficient." It is nothing more than an approximate value for the sodium and potassium salts in the water, and obviously would not apply unless finely divided solids were also present. If sodium salts and suspended solids were both measured a very good guess could be made as to the foaming susceptibility of the water. Unfortunately, however, it would not be safe to reason in the converse way, because some waters that are very low in sodium salts and suspended solids nevertheless will foam.

A foam test is still to be devised. Some preliminary work in the author's laboratory suggests the possibility of developing something practical from so simple an operation as blowing air into the water to be tested. If the air enters in very fine bubbles, as when blown through a porous septum, a foam seems to be produced, even at room temperature, in all waters that foam on boiling, and vice versa. There is also the "membrane meter" of Wo. Ostwald and Steiner (footnote 7). These investigators found that when the level of a liquid in a capillary tube is raised or lowered the rate at which the liquid surface returns to its original position is inversely proportional to the foaming susceptibility of the liquid. The original paper must be consulted for the details of the experiment.

In applying these or any other test to a boiler water, however, one must not forget that the raw water and the same water after it has been subjected to the high temperature of the interior of a modern steam boiler are by no means the same things. Nevertheless the development of a foam test is worth some research.

PRIMING

"Priming" as used in this section has a special meaning, namely, the projection of water into the steam space due merely to violent ebullition. In most cases, perhaps, it results from the ebullition of spasmodic violence accompanying the breakdown of a condition of superheating. Unpublished work done in the author's laboratory shows that in glass flasks at least it is far easier than has been supposed to heat water above its normal boiling point for the pressure of the moment. Indeed, the water may be boiling, that is, copious bubbles of steam may be rising through it, and yet its temperature will be one or two degrees fahrenheit above the normal boiling point. If now, with the water in this condition, it is subjected to a shock of some sort, like the introduction of a little solid matter or the addition of a slug of water from the outside, the superheated state breaks down and the stored-up energy is dissipated by a few moments of violent ebullition, the temperature of course falling to the normal.

Every one of course knows these facts about the superheating of liquids, but it is doubtful if many know how common the phenomenon is.

Other experiments were of the following nature. Flasks were so equipped that the steam from the boiling water in them escaped through a small orifice and therefore some inside pressure could be maintained and at the same time have the boiling proceed. If now a large valve in the stopper were opened the pressure of course dropped, the water was left at a temperature a degree or so above its normal boiling point for the lower pressure and consequently there was violent ebullition for a few seconds, so violent that large slugs of water were projected into the steam space.

If a similar situation can occur in a boiler when the steam valve is rapidly opened, the violent ebullition that will follow for a few seconds may easily throw slugs of water into the steam line. The important point to note in these experiments is that this "priming," as it is called, can take place with pure water. It is independent of the conditions of film formation, etc., that are necessary for "foaming," in other words, it is a separate phenomenon and therefore merits study as such.

The question naturally arises, what happens when the flasks are charged with sodium-salt solutions alone, suspended solids alone, or with both sodium salts and suspended solid matter? The answer is, that dissolved matter alone or suspended matter alone increases the "priming" only slightly, but when both dissolved and suspended matter are present the priming is many fold that of pure water. The effect described in No. 3 above can be observed at times, that is, the water lifts by becoming a mass of steam bubbles. Owing to the fact that "priming" is so greatly increased in a water in which the conditions for the formation of stabilized films also exist, it is difficult to distinguish between "priming" and "foaming." In the situation just described it would be logical to say that the "foaming" was greatly increased during a few seconds by the "priming."

THE PROJECTION OF DROPLETS OF LIQUID BY BURSTING BUBBLES

So far as the author is aware, no studies have ever been made of the nature of evaporation from the standpoint of the projection of droplets of liquid into the steam space by the bursting of bubbles. Perhaps very slight additions of the right substances to a boiler water would cause its boiling to proceed with such "smoothness" that little or no water would be thrown up. The idea is fanciful, but nevertheless is worth at least a little laboratory experimentation.

REMEDIES FOR FOAMING AND PRIMING

The two outstanding methods of reducing foaming and priming are (1) reduction of the concentration of sodium salts, suspended solids, or other offending substances by blowing down the boiler, and (2) the introduction of castor oil into the boiler water. The first remedy is efficacious in about the extent to which the concentration of the offending substances in the water is reduced. Such a relation is so obvious that no theoretical discussion is needed. It is equally obvious that there is a heavy loss of energy in wasting water that has been heated to the temperature of the boiler, and therefore blowing down has severe limitations. Finally, the plan has no effect when the foam producing impurity is in the raw water.

Remedy No. 2, the use of castor oil, is perhaps the most interesting and effective treatment applied to industrial water. Its effect on the stabilized foams resulting from dissolved salts and suspended solids is like a touch of magic. A mere trace of this oil, less than 0.001 per cent by volume, causes the instant disappearance of the type of foam referred to above.

In actual practice castor oil is seldom or never used as such because it is not miscible with water and therefore difficult to apply in a uniform way. The general procedure is to prepare an antifoam compound by emulsifying the oil with starch and other ingredients to give a mixture containing 14 to 15 per cent of oil. This will mix uniformly with a large quantity of even cold water so that the introduction of any desired amount into the boiler is easy.

On one of the Ohio railroads the rule[14] is not to begin using antifoam till the boilers begin to foam, which usually takes place when the concentration of dissolved solids reaches 3000 parts per million (175 grains per gallon). A pint of anti-foam compound, containing 16 per cent of castor oil, is then put into the tender tank, which holds 5000 gallons of water. This would mean a concentration of less than 4 parts per million (about 0.2 grain per gallon) of actual oil in the water, and yet by its use the boiler can be kept going till the concentration of dissolved solids reaches double the value given above.

This effect of castor oil in inhibiting foam is apparently confined to that type of foam in which the films are stabilized by suspended solid matter. "Apparently" is used advisedly because the matter has never been systematically studied. A few experiments in the author's laboratory seemed to show, for example, that the oil had no effect on a soap foam.

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[14] Personal communication from C. P. Hoover.

A few other oils also inhibit foam as castor oil does, but for one reason or another have never come into use. Bardwell[15] found that pine-tar oil worked satisfactorily up to 140 lb. pressure, but not beyond. Incidentally, it might be remarked here that during the World War many experiments were probably made in search for substitutes for castor oil as an anti-foam. If this is true they ought to be recorded somewhere.

There is little or nothing on record concerning the prevention of foaming due to dissolved vegetable matter. French[16] found that alum served to prevent the foaming caused by dissolved vegetable matter in a highly colored Florida surface water. This is interesting because the generalization is perhaps warranted that such foam-producing substances can be rendered harmless by adsorbing them on precipitated aluminum hydroxide.

When the question of a physico-chemical theory of the destruction of foam by castor oil is raised, the answer must be, there is no theory. One may guess that the action is due to the destruction in some way of the stabilizing action of the suspended solids rather than to any effect on the liquid films. Perhaps the best way to get suggestions on this point is to study the data of ore flotation. Edser's paper (footnote 12) in this connection is admirable.

FOAMING AND PRIMING AS A RESEARCH PROBLEM

Since the underlying purpose of this paper was to suggest points of attack in research work on the problem of foaming and priming of boiler water, it will be worth while now to classify the suggestions offered above. They fall naturally into two groups.

I. Research with the object of finding the fundamental causes of foams and stabilized films in such water solutions as may occur in a steam boiler. This is a laboratory problem calling for measurements of surface tension, surface concentration, and viscosity, thickness of liquid films, angles of contact between solids and liquids, and long, patient experimentation with one combination of materials after another. Coincident with the above will be a line of experimentation with autoclaves or small experimental boilers.

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[15] R. C. Bardwell. Personal communication to the author.

[16] D. K. French. Personal communication to the author.

This is the kind of work that is adapted to university surroundings in which the necessary scientific instruments, books, and journals are to be found.

II. Research involving experiments with actual steam boilers under working conditions. This is preëminently the point at which the practical man comes in, and it is fortunate that the organization of the committees having this work in charge (footnote 4) includes practical as well as theoretical men. The prospects for coöperation are fine.

There is of course no reason why these two groups of research should not mix in any proportion that circumstances may bring about, and it is certainly the wish of the author of this paper that they should be so mixed.

EMBRITTLEMENT OF STEEL

PROGRESS REPORT OF SUB-COMMITTEE No. 6 ON EMBRITTLEMENT OF METALS[1]

By Alexander G. Christie, *Chairman*

The work of this Committee has been confined to the consideration of the embrittlement of steels used in steam boilers. This subject has been receiving much study both here and abroad and many conflicting views have been submitted to the committee for consideration. These have been carefully considered and analyzed.

There are two schools of thought in regard to this subject. Certain engineers, after studying embrittlement from many angles, have been led to the conclusion that such embrittlement as occurs is promoted by the presence of caustic in the waters in the boiler resulting from the occurrence of sodium carbonate in the feed-water. Other engineers, also after careful study of the phenomena, have concluded that other causes contribute to this type of failure and that the presence of caustic is not the controlling factor.

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[1] The personnel of Sub-Committee No. 6, on Embrittlement of Metals of the Joint Research Committee on Boiler Feedwater Studies is as follows:

Alexander G. Christie, *Chairman*, Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md.

Henrich Kriegheim, Technical Manager, The Permutit Company, 440 Fourth Avenue, New York, N. Y.

A. S. Behrman, International Filter Company, 333 West 25th Place, Chicago, Ill.

John H. Buell, Manager of Operations, Oklahoma Power Company, Tulsa, Okla.

R. E. Coughlan, Chicago and Northwestern Railroad, Chicago, Ill.

D. K. French, Dearborn Chemical Company, 310 South Michigan Avenue, Chicago, Ill.

John Hunter, Mechanical Engineer, 805 Merchants-Laclede Building, St. Louis, Mo.

J. B. Romer, The Babcock and Wilcox Company, Bayonne, N. J.

Albert E. White, Professor, Director, Department of Engineering Research, University of Michigan, Ann Arbor, Mich.

R. S. Williams, Professor of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

This report will summarize the evidence and reasoning of both schools of thought and will attempt thereby to give engineers a definite idea of the problems involved. The Committee does not believe, in view of the data before it, that it is possible at the present time to reach any final conclusions regarding the cause and remedy of this trouble. Certain facts seem to be established and these will be presented. The Committee also makes certain recommendations at the close of its report.

The following outstanding facts are presented as indicating the present status of knowledge of the phenomena:

a. Embrittlement of boiler metal is an established fact and not a myth as believed by some engineers.

b. The difficulty has not been encountered in any one section of the country, although there are certain areas where failures of this kind have been more prevalent.

c. In most cases where these failures have been experienced, the water has contained relatively high concentrations of carbonate, bicarbonate or hydrates of soda and these waters have been low in sulphates or chlorides of soda. Some cases of embrittlement of boiler metal have occurred, however, with waters where the concentration of sodium salts was low.

d. Embrittlement is a function of excessive stresses in the metal, and the phenomenon apparently does not occur in the absence of stresses beyond the elastic limit for the metal.

e. It has been shown experimentally that embrittlement of boiler steel may be produced at will in the presence of excessive amounts of hot caustic soda (20,000 grains per gallon) when the metal is under tension beyond the elastic limit. The phenomenon takes place usually by the combined action of high stress and high chemical concentration. These facts have been established by laboratory experiments, but the element of time affecting the phenomenon has not been established.

f. Laboratory experiments and experience in practice indicate that the embrittlement of the metal may be inhibited by maintaining a specific ratio between the sodium carbonates and sulphates present in the water.

g. Failure of the metal progresses by intercrystalline fracture. In practically all cases there is no deformation of the grains.

h. One investigator has determined that a similar phenomenon may be produced by calcium nitrate.

Various investigators are by no means in accord concerning the basic cause or causes of the phenomenon, and much discussion has arisen as a result of the two schools of thought. There are certain points, however, upon which there seems to be general agreement. These are as follows:

a. Brittleness of boiler steel may occur in the presence of high concentration of caustic soda and result from straining the metal beyond the elastic limit.

b. Failures of this kind are intercrystalline in character.

c. The cracking of metal occurs in practically all cases along the line of the rivets and on the dry side of the plates.

Certain investigators believe that the brittleness of metal is affected by the absorption of cathodic hydrogen, and that the rapidity of the action is accelerated by stresses in the metal. This view has not received universal acceptance.

Still others hold that embrittlement is due to the presence of such impurities as iron sulphide at the grain boundaries, which are dissolved by the action of caustic soda or other chemicals.

Some engineers believe that embrittlement is due partly to certain inherent characteristics of the steel and partly to stresses from deformation and riveting in the process of manufacture augmented by the stress due to the working pressure in the boiler. Evidence has been submitted to confirm this view.

A REVIEW OF INVESTIGATIONS AND OPINIONS ON EMBRITTLEMENT

As early as 1866[2] Graham made the interesting discovery that red-hot iron was penetrated by hydrogen and that a portion of the hydrogen was retained by the metal after it had cooled down. Caillet[3] and Johnson[4] arrived at a somewhat similar conclusion and demonstrated that hydrogen generated electrically was absorbed by iron at room temperatures. They showed further, however, that hydrogen in a gaseous form apparently had no effect upon the metal. In Johnson's work it was shown that soft iron became embrittled in contact with electrolytic hydrogen. It was further shown by Johnson that the treatment of the iron with acid, prior to contact with the gaseous hydrogen, greatly accelerated the rate of embrittlement of the metal.

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[2] Proceedings of the Royal Society, vol. 17, p. 219, 1869.

[3] Comptes Rendus, vol. 80, p. 319, 1875.

[4] Proceedings of the Royal Society, vol. 23, p. 186, 1875.

It was reported by Thompson[5] that fairly high concentrations of solutions of soda at boiling temperatures had no appreciable effect on the properties of soft iron. It was also shown by the same investigator that soft iron was much more seriously affected by boiling water. Somewhat similar results were obtained by T. S. Fuller.[6] This investigator showed that the rate of absorption or penetration of hydrogen through a sample of electrolyzed iron was practically the same with 1 per cent caustic soda as when tap water was used. W. D. Andrews reported the results of experiments in the Transactions of the Faraday Society, 1914, stating that strips of steel kept in concentrated sodium hydroxide solution at 212 deg. Fahr. for a period of from one to seven weeks were seriously embrittled. Hydrogen was evolved as the result of the action of the caustic soda. Most widely quoted experimental studies on this subject are those of S. W. Parr,[7] published in the University of Illinois Bulletins in 1917 and by Parr and Straub in 1926. The conclusions reached by these investigators are as follows:

a. Embrittlement in boiler plate is caused by the combined action of stress and chemical attack. The stresses are inherent in the construction and in the operation of the boiler, while the chemical attack is caused by sodium hydroxide in the boiler water.

b. Certain methods of water treatment tend to convert some safe waters into the characteristic type of water which produces embrittlement.

c. The presence of sodium sulphate in the feedwater and undecomposed sodium carbonate in the boiler water tends to retard the embrittling effect of carbonate waters, and if these are present in proper proportions they will stop it entirely.

d. Methods for introducing sulphates in boiler waters have been worked out to the point of practical application.

R. S. Williams and V. O. Homerberg report in the Transactions of American Society for Steel Treating, April, 1924, the results of their experimental studies carried on at the Massachusetts Institute of Technology. The conclusions of these investigators are as follows:

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[5] Journal of Society of Chemical Industry, 1894.

[6] Transactions of the American Electrochemical Society, 1919.

[7] University of Illinois Bulletin, January 1, 1917, no. 94, and June 22, 1926, no. 155. (*Note:* Engineers interested in embrittlement should study carefully the last bulletin (no. 155) of Parr and Straub.)

a. During the crystallization of steel, the impurities, to a considerable extent, are rejected to the grain boundaries.

b. The oxides and sulphides are two of the prime factors in caustic embrittlement.

c. The oxides are reduced under the influence of cathodic hydrogen.

d. The sulphides are removed due to the action of hot caustic soda solutions.

e. The removal of the sulphides produces a surface condition favorable to progressive corrosion.

f. Assuming that progressive corrosion starts with the removal of the sulphides, the corrosion will be greatly accelerated if the material is stressed. Furthermore, when the steel is under tension there is a tendency for the matrix to pull away from the inclusions at the grain boundaries and in this manner to produce small capillaries into which the corroding solution can penetrate.

g. In stressed areas containing oxides, the volume increase, due to the reaction with cathodic hydrogen, may produce stresses which, added to those initially present, may cause cracking.

h. It seems evident that hydrogen acts in three ways to produce embrittlement: first, the temporary brittleness caused by absorbed hydrogen (as in acid pickling), second, it acts to reduce oxides, and third, its effect due to the change in volume at the grain boundaries, resulting because of the production of water. This latter volume increase would create a stress which, added to those originally present, may cause cracking, especially at those points where these stresses are at a maximum.

The 1922 Report of the Prime Movers Committee, National Electric Light Association, on Treatment of Feed Water, in discussing this phenomenon, gives the general characteristics present in the embrittlement of boiler plate as follows:

a. Occurrences ordinarily limited to the joints of the boiler.

b. Occurrence only in parts of the boilers reached by the water. This is most noticeable in girth joints, as up to the place reached by the water (not necessarily the normal water line), cracking is found, and beyond that point the plate is unimpaired.

c. Occurrence in the various members of the joint; that is, in the rivets as well as the plates, in both plates of a lap joint, or in plates and straps of butt joints.

d. Occurrence in rolled plates, cast steel or cast iron, according to the construction of the boiler.

e. When a plate is cracked, the line of the crack on the surface of the plate in contact with the surface of another plate is longer than the line of the crack on the other surface of the same plate (i.e., embrittlement starts at the surfaces in contact).

f. Extreme irregularity of the cracks with sharp changes of direction; paralleling without any marked tendency to join; in other words, the exact position of a crack is not determined by the stress due to the boiler pressure, though the general area affected may be.

g. Brittleness of the material under shock and fatigue, with very little indication of brittleness under static tests, and marked localization of the embrittlement to the joint area.

h. Loss of embrittlement (not necessarily total) with time when the boiler is removed from service, coupled with a marked degree of removal of embrittlement by heating at temperatures far below those required for ordinary annealing.

i. A plentiful deposit of a black, powdery substance on the affected surface which on analysis is principally an iron oxide.

Since the location of cracking of this sort is selective with respect to the parts of the seams reached by the water of the boiler, reference should be made to the feed conditions and apparently with the following conditions in mind:

a. Solubility will be of prime importance for the reason that a highly soluble substance may be present in heavy concentration without depositing anything on the metal to mechanically protect it.

b. These substances should not attack the metal in the concentration in which they usually occur in a boiler, but should attack the metal in the higher concentration that can build up in restricted areas like the boiler joints.

c. Acids can be eliminated from consideration, as they attack the entire metal surface at any concentration that could occur in boiler practice.

d. Substances of high specific conductivity would increase the corrosive effects resulting from potential differences in the boiler structure.

e. Substances such as calcium and magnesium carbonates, calcium sulphate, etc., being incrusting salts and of low specific conductivity, may be eliminated from consideration for either reason alone.

The soluble salts generally found in practice are given in table 1, column "A" showing solubility in grams per 100 cc. of water at 100°C., column "B" showing equivalent conductivity at 18°C. From this table, sodium hydroxide has the greatest index of solubility and conductivity. Sodium chloride is relatively low in both solubility and conductivity, and by itself is not known to be corrosive under boiler temperatures at any concentration. Magnesium chloride and calcium chloride, while higher than sodium chloride in solubility and conductivity, have hydroxides that are very low in solubility, and corrosion from these substances occurs even at low concentration on all exposed surfaces. Hydrolysis of sodium carbonate is very considerable under boiler temperature, and within the range of usual boiler concentration in its effect it may be regarded as though it were sodium hydroxide. Sodium sulphate will ordinarily occur in boilers as the result of the initial use of sodium carbonate, so that for all of the foregoing reasons sodium hydroxide should (a priori) be considered as the most probable cause of the trouble. It is to be noted also that sodium hydroxide is only very slightly corrosive at boiler temperatures in solution strengths such as occur in the main body of the water in the boiler, but is actually highly corrosive in the stronger solutions that can occur in the joints.

TABLE 1

	"A" Solubility	"B" Conductivity
Sodium chloride	39.12	92.0
Magnesium chloride	73.0	98.1 ($\frac{1}{2}$ $MgCl_2$)
Calcium chloride	159.0	88.2 ($\frac{1}{2}$ $CaCl_2$)
Sodium sulphate	42.5	78.4
Magnesium sulphate	73.8	76.1 ($\frac{1}{2}$ MgS_4)
Sodium carbonate	45.5	72.9
Sodium hydroxide	339.0	203.4
Potassium hydroxide	178.0	228.0

Note: Potassium hydroxide, while of most exceptional occurrence, is included on account of the values of its constants as compared with sodium hydroxide.

F. B. Porter[8] has drawn the following conclusions from the result of his studies:

> At the University of Illinois, boilers had been operated intermittently for twelve years at 100 pounds pressure on the soft alkaline water without trouble.

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[8] Paper read before the American Chemical Society, Tulsa, Okla., April 5, 1926.

Three years' operation at 140 pounds pressure put four drums out of service, and we judge that there were four drums that withstood this same operation that were still unaffected. There is a large number of boilers at Fort Worth, Dallas, Waco, McKinney, Houston, Baton Rouge, Louisiana, and other points that have been operating on soft, alkaline water on pressures from 150 to 210 pounds that have never shown indications of embrittlement. The Trinity sands water in Texas contains enough sulphates to give a sulphate ratio of something like three of sulphates to one of alkalinity, but the other artesian waters used at the plants just mentioned have much less sulphates, some of them only a very small amount. In one plant at Dallas, two plants out of four at Houston, and at one Waco plant an occasional drum has been lost through embrittlement, and in practically every case other drums which have seen the same service with the same water are still in operation, and other plants using the same water have never been affected.

The question of the contributing causes of this peculiar type of embrittlement is important in suggesting remedies and in adjusting a settlement on installations on which renewals are required. This trouble occurs often within six months to three years of the time the boilers are put in service. The cracking occurs in regions of little stress. The actual stress in boiler operation in butt-strap seams is small compared with other sections of the drum. The stresses in the metal set up in the fabrication of the drum in the area adjacent to the rivets may be high. It is a difficult question to decide whether boiler-water leakage into the seams evaporates and produces high concentration and starts embrittlement, or whether the embrittlement and cracking start and the leaks promptly result therefrom. If the leaky condition comes first, it probably does not make very much difference what the concentration of the boiler water is, for the reason that a concentration even to the solid can rapidly occur in the seam as soon as the leak starts.

The impression has been general that it is only overtreated, softened waters that would be likely to cause embrittlement. A recent case of embrittlement where zeolite-treated water only had been used would indicate that any softened water may furnish one of the requisite causes for embrittlement. The mention above of pressures obtaining in boilers and intermittent operation as compared with continuous operation, leads us to make the general observation that we believe that higher pressures and more continuous operation tend to increase the likelihood of embrittlement taking place, but this is as strong as this statement can be made, for some boilers operating under the same pressure and on the same water may be affected and some of them not. One hundred and forty pounds at the University of Illinois, which caused the loss of four drums, is considered a very low water pressure on large plants today.

In conclusion, it seems at the present time that the only explanation of caustic embrittlement that will account for this condition being present in some drums of some plants and absent in other drums of these same plants, and absent in all the drums of other plants, using the same waters and the same type of waters, is that embrittlement is due to overstrained or dirty steel and causticity in contact with same.

Mr. McAdam of the United States Naval Engineering Experiment Station, in a discussion of Professor Parr's paper at the 1926 meeting of the A. S. T. M., reported that he produced intercrystalline cracks in specimens subjected to fatigue tests when he cooled them during the test by directing a jet of water against the specimens.

Mr. Patterson of the Solvay Process Company, in a discussion of Professor Parr's paper (loc cit.), pointed out that caustic soda cannot concentrate very appreciably within the interstices of a seam as long as the seam is tight, since the boiling temperature of a more concentrated solution is higher than that of a more dilute solution, so that as soon as a concentration of the caustic soda solution within the seam rises above that of the main body of water in the boiler, further concentration in the seam stops, since no further evaporation will take place. Therefore it will be impossible to concentrate the solution within the seam to the degree found active by Professor Parr, as long as the seam does not leak. Mr. Patterson has directed attention to the possibility of oxygen in the water as a possible offender accelerating embrittlement.

Mr. Applebaum of the Permutit Company has quoted the work of Mr. Jones:[9]

> In a fresh solution, stressed steel cracked in a few days, but after the solution had been in use for some time the steel became coated with a black deposit of oxide and cracking was inhibited. This is not solely due to the alteration of surface of the steel since the solution now fails to crack fresh similar specimens which are introduced and which themselves become coated much more quickly than the original specimens. A deposit consisting of magnetic oxide and some carbonaceous matter accumulated at the bottom of the vessel. The inhibiting effect of the presence of oxide lends support to the view that cracking is brought about through the agency of hydrogen.

As a result of the experience and extensive experimental work of the Babcock and Wilcox Company, the following conclusions have been drawn by the company concerning this phenomenon and are reported in the 1925–1926 Report of the Prime Movers Committee, N. E. L. A. on Treatment of Feed Water.

Certain characteristics of this cracking are as follows:

1. The cracks all occur below the water level.
2. In at least one of these plants, cracking of boiler drums has continued over a period of at least twelve years. In some cases,

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[9] Transactions of the Faraday Society, vol. 17, p. 149.

replacement drums cracked in a shorter period of time, notwithstanding special care in manufacture.

3. All of these cracks have occurred in seams under tension, having factors of safety, as normally calculated, from five to approximately ten.

4. Examination of the type of plate showing cracks has definitely shown that this cracking occurs in plates having practically perfect chemical and physical characteristics, as well as in plates which may not have as good characteristics.

5. These cracks have developed in cast steel, steel boiler plate and most perfect rivet steel.

The characteristics of the cracks themselves in general are:

a. They do not follow the line of maximum stress.

b. While in general they run from one rivet hole to another, they run more often in entirely different planes, so there will be a crack from one rivet hole passing parallel to a crack from another rivet hole.

c. They frequently run from each of two adjacent rivets past each other for at least half their length without joining, or they even cross the full ligament from rivet to rivet without joining, leaving little islands of plate.

d. They are irregular in direction when fully developed, having numerous sharp angles, and the final direction of the cracks is sometimes 90 degrees from that at their beginning.

e. They never extend into the body of the plate beyond the lap of the plate.

f. They sometimes occur on the solid plate of the seam and do not connect with the rivet holes.

g. The cracks are not accompanied by elongation of the plate.

h. Photomicrographs of these cracks indicate that they are intercrystalline.

i. The cracks start on what is usually termed the "dry" face of the joints.

j. As stated before, the cracks all occur below the water level of the boiler.

The 1925–1926 report of the Prime Movers Committee, National Electric Light Association on Treatment of Feed Water, contains a statement by the Permutit Company in which they summarize the factors that enter the problem, as follows:

In our opinion there are four factors which must be considered in tracing the origin of cracks in boilers:

a. The quality of the steel.

b. The stresses either existing in the plate before fabrication, or introduced during fabrication, operation and repair, in addition to the calculated working stresses.

c. The temperature to which the steel is exposed when under the total stress and the period of time during which the total stress is acting.

d. The composition of the feedwater as well as the boiler salines.

A number of interesting comments have been received, some of which are reported herewith. The president of a firm manufacturing chemical machinery in a letter to the Chairman states as follows:

> In the manufacture of caustic soda we find that the eventual failure of what is known as a caustic soda pot is probably due to the continued heating and cooling of the cast-iron pot rather than to definite caustic or chemical action. It is true that we do have some of this caustic or chemical action, but the industry seems to agree fairly well that the reason for the final destruction of caustic soda pots is that continuous heating and cooling of the vessel itself bears the greatest burden of the failure of the casting.

A leading consulting engineer in a letter to the Chairman states:

> The full nature of conditions tending to cause caustic embrittlement is far from definitely determined. The evidence while pointing to existence of caustic in solution as probably the most frequent cause, would indicate, however, that caustic by no means occupies a unique position in that respect.

A prominent chemical engineer writes as follows:

> I fail to find any direct tie-up between the character of the water and embrittlement. Such tie-up as does exist is based very largely on "hunches," and not on any real data. That is, we know that certain of the water analyzed is poor water for boilers. We deduce, therefore, that this water will produce caustic embrittlement. We examine the boilers and we find cracks and fractures. The boiler even in certain sections may manifest considerable brittleness. We put the two things together and reach the conclusion that the boiler feedwater has been responsible for the cracks and other failures, through the action of caustic embrittlement. Such reasoning may be correct. It does, however, lack the continuity of proof, which we, as engineers, should demand.

An interesting case of embrittlement in a pressure vessel normally containing hot caustic soda in rather high concentrations, was recently called to the attention of the Chairman. This case was very thoroughly investigated and the conclusion reached that the failure was apparently due to the structure of the plate itself at the time it was fabricated. Microscopic examination showed an almost perfect Widmanstaetten structure (a structure usually formed in cast steel) in the cross-section of the metal. In view of the inherent weakness of this structure, it is doubtful whether the caustic had any influence in causing the failure of the shell.

A leading British metallurgist who has devoted much study to this subject and from whom the Committee requested a statement, has written the Chairman in a private communication as follows:

> I do not know of any recent publication in this country bearing on the matter, but I have followed with interest what has been done in America and Germany. With regard to Professors Parr and Straub's paper, I have read it with very great interest and appreciation. While I find some difficulty in believing that a concentration as high as their experiments suggest, can ever be produced in a boiler, even in the fissures or seams, and while I also think that a stress exceeding the yield point can only be caused by the existence of several local stresses due to excessive riveting pressure, etc., I yet feel that their present work has put the matter on a sounder basis than formerly. Their experiments appear to me to establish the fact that caustic soda when sufficiently concentrated can act as an accelerator of cracking in heavily stressed steel. Whether this can be regarded as by any means a full explanation of what occurs in boiler practice, is quite another matter and remains to be established by further work. The only light that I can throw on the whole question is that, so far our experiments—made with a view to producing fracture under prolonged loading in mild steel stressed to various intensities at a temperature of 300 deg. cent. in air—have failed to produce fracture even after a number of years' exposure. This experiment certainly suggests that some subsidiary agency of a corrosive nature is necessary to produce failure in a reasonable time, although it is quite possible that the particular sample of steel which I employed was not one subject to intercrystalline fracture under prolonged loading. There is to my mind no doubt at all that the nature and condition of the steel plays a large part in the matter.
>
> The only immediate suggestion I can offer is that experiments on the lines of those made by Parr and Straub should be carried out on steels of different origin, particularly on acid as well as basic steels and after various forms of heat treatment, including a heat treatment which shall render the carbide granular or spherulitic instead of lamellar.

A consulting engineer of prominence, who has had over forty years' experience in chemical and mechanical engineering, has furnished the Committee the following opinion relating to the problem of embrittlement.

> The cases of embrittlement which have come under my observaton have been so contradictory that I am led to believe that only certain qualities of

steel are affected. By quality I mean physical quality. The chemical analysis seems to throw no light on this subject, and in the same apparatus one sheet of steel will develop minute cracks, which in many cases are in the middle of a sheet, while other sheets in the same apparatus and under the same conditions, last indefinitely.

I have never known any case of embrittlement in boiler shells or steam drums of boilers, except with very concentrated liquors. I once tried the use of a water-tube boiler for concentrated caustic liquor from 20° to 30°B. These boilers gave no trouble while in this service for a period of several months, but after being returned to ordinary boiler service, I found one of the seams of one of the drums had a crack along the calking of the longitudinal seam nearly three feet long, and the inside had a number of minute cracks extending from one rivet hole to the others, sometimes in two or three directions. This seam was cut out, taken apart and examined very carefully. The water was being treated with soda ash and lime and contained a small amount of caustic soda which was, however, not allowed to concentrate very much, but it was evident that if the water could leak into the space between the laps which were not very well drawn together, the caustic might concentrate in that particular seam and have an action on the steel which would not be possible with the low concentration.

Following this were several others of a similar kind, where the drums had been used for concentrate caustic liquor and cracks were found by examination with a microscope in a number of other drums, always in the seams between rivet holes where the joints had been pulled together with drift pins, or where the severe calking had been done.

I have also noticed that steel tanks containing hot 40°B. liquor are gradually embrittled, especially in the seams. When struck with a hammer, after these tanks have been long in use, the rivet heads will pop off, showing in many cases cracks which are part way through the rivets, which had evidently been there a long time, but alongside of them were other tanks with 20°B. liquor that had been in use for thirty-five years, some of them wrought iron, some steel, which were not affected.

I have noticed in some cases where cast-iron pipe joints are held together with bolts and slight leaks of caustic liquor occurred, which ran over the bolts, that these bolts were broken in two in two places, or many of them half-broken in two. In one case of a large B. & W. "W"-type boiler, a lower drum developed some cracks in one sheet. Six other boilers running under the same conditions gave no trouble. A spare drum was ordered which has never been put in, and while the failure was laid by the manufacturers to embrittlement, and several learned reports were written on the subject, I have never been satisfied that the cracks were caused by the very slight amount of caustic soda present in the water.

Professor Baumann in a lecture before the Association of Steam Boiler Inspectors at Zurich, Switzerland, on September 7, 1926, stated that the evidence from laboratory tests indicated that the presence of caustic soda is not essential to the formation of intercrystalline cracks.

Dr. Guilleaume in a recent report[10] stated that in all cases where steel failed in service, the failures were traced to thermal and mechanical causes. In no instance was it indicated that caustic soda had been responsible for the development of the fracture of the metals.

Last year, two important[11] contributions on this subject appeared in Germany. Dr. Bauer, of the Metallographical Institute of Dahlem, has shown that hydrogen in contact with metal and under high pressure (up to 3000 pounds) will not affect the strength of the metal when the contact takes place at room temperatures. Dr. Bauer has demonstrated, however, that relatively small amounts of hydrogen in contact with iron or steel at boiler temperatures are readily absorbed by the metal, materially reducing its tensile strength.

Professor Thiel's research studies have shown that 77.5 per cent of caustic soda may concentrate in the clearances between the boiler plates, resulting in reducing the tensile strength of the boiler. This action, according to Professor Thiel, is due to the absorption of hydrogen which is released from the caustic soda when the sodium unites chemically with the iron.

An enlightening editorial on the subject of embrittlment appeared in *Power* in the August 17, 1926, edition of this periodical. A portion of this comment is quoted since it confirms the Committee views that future research is highly desirable.

> Are there not several kinds of causes for embrittlement? Are all embrittlement cracks from the same cause? The boiler user is intensely interested in the answers to such questions.
>
> But the boiler user cannot be content to sit idly awaiting the conclusions of what is to him in a measure an academic question. After all, he cares little by what name his trouble is called. His demand is for some remedy that will enable him to operate safely. Whether the remedy is scientifically rational or purely empirical is interesting, but not vital to him. Even a "hunch" is good enough for him if it works. True, there may be a cheaper and better way to be developed through further research, and this the operator wants, but he dare not wait for it. He must do something now.
>
> What shall he do? Two factors are involved—stress and water conditions. Perhaps the elimination of either alone will cure the disease, but since both are under suspicion, why not do all that can be done to eliminate both? Severe internal stress is admittedly bad on all counts. Let every effort be made to

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[10] Report presented to the Association of Large Steam Boiler Plants at Cassel, Germany, September 17, 1926.

[11] Papers read at the Association of Owners of Large Boilers at Darmstadt, December, 1925.

eliminate it by insisting on first-rate material and the best possible shop practice. Certain materials in solution in the feedwater seem also, in some instances at least, to be a contributing cause. Let care be taken in adding such things to the water or in neutralizing them if they are already present.

Your Committee has attempted to summarize the work of the various investigators and to present the viewpoint of those who have advanced the theory of embrittlement due to high concentrations of caustic soda and that of those rejecting this premise. The latter call attention to the following phenomena which may influence the failures.

Gaseous hydrogen from any source may penetrate steel and be occluded by it, resulting in embrittlement of the metal. This phenonenon may take place not only from caustic soda but from any other source. Excessive strains set up in the metal may be the primary cause for embrittlement and the source of intercrystalline cracking. Intercrystalline cracks may be developed in ferrous and non-ferrous metal due to improper thermal treatment in the manufacture of the metal.

The advocates of caustic embrittlement tend to direct attention to the quality of water as the offending agent rather than the material in the boiler or the method of fabricating the equipment. Failures of this kind have occurred largely in certain sections of the country where the water used for boiler feed contains relatively large quantities of sodium carbonate and bicarbonates and is low in sulphates or chlorides. In many instances, the difficulty has disappeared entirely by changing the source of the feedwater and using water that did not have these characteristics or by treating the water chemically so as to maintain a predetermined ratio between the carbonates and sulphates.

The difficulty has not been confined to boilers of any one manufacturer, thereby tending to eliminate the theory of faulty design and construction or dirty metal. Embrittlement of metal has been produced by investigators by duplicating conditions that theoretically should be favorable to producing the characteristic intercrystalline cracking of the metal.

A complete bibliography of the subject of embrittlement of metals has been prepared by the Engineering Library, 29 W. 39th Street, New York, copies of which can be secured for a nominal charge by any one interested in this subject.

RECOMMENDATIONS

Most of the experimental work which has been carried on has been with waters high in carbonate or bicarbonate of soda. Little information is available concerning the possibility of embrittlement of boiler metal in waters low in these salts. It has already been demonstrated in one case reported to the Committee that embrittlement of boilers may and has resulted from the use of feedwater low in sodium salts.

Little information is available concerning the effect of dissolved gases in accelerating the phenomenon of embrittlement.

High pressure as a contributing agent has not been established. There are many other factors entering into the problem which up to the present time have received no special attention from investigators of these problems. It is evident that there is much still to be learned concerning the cause or causes of intercrystalline cracking of boiler plate and much is to be learned concerning the methods of controlling the contributing factors.

The preceding paragraphs present a brief digest of the great mass of data submitted to the Committee. A careful study of all of this material has led to the formulation of the following recommendations:

1. In view of the wide diversity of opinion on the cause of embrittlement, extensive research should be started to determine the influence of all possible contributing factors.

2. Plans for such research should be formulated to give cognizance to causes of embrittlement other than those which may result from the use of waters in which high concentration of caustic soda is potentially possible.

3. Not only must the causes of embrittlement be determined, but means of preventing its occurrence under all conditions should be developed as soon as all contributing causes are known.

4. Since the plate ligament or the rivets in riveted joints may be stressed beyond the elastic limit of the metal, a study of other means of joining plates such as welding, is a logical step in the elimination of embrittlement troubles.

5. This research may be carried out in University laboratories, but funds must be obtained to finance this experimental work.

6. This Committee should be continued to coördinate the research work and to report developments in the study of Embrittlement of Metals.

MUNICIPAL WATER SUPPLIES AND THE EFFECT OF TRADE WASTES IN RELATION TO THE USE OF WATER IN POWER-PLANT PRACTICE

Progress Report of Sub-Committee No. 7 on Municipal Water Supply in Relation to Boiler Use[1]

By V. Bernard Siems, *Chairman*

The activities of this Committee during the past year have been devoted to two distinct problems affecting the treatment of water for steam-making uses and for condenser purposes.

a. Collection of data relative to the quality of water supplied by municipalities and its effect on the cost of operation of industrial water treatment systems.

b. A study of the effect of trade wastes and domestic sewage discharged into surface streams used as a source of supply for power-plant uses.

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[1] The personnel of Sub-Committee No. 7, on Municipal Water Supply in Relation to Boiler Use, of the Joint Research Committee on Boiler Feedwater Studies is as follows:

V. Bernard Siems, *Chairman*, Water Engineer, City Hall, Baltimore, Md.

W. R. Abbott, Chief Engineer, Commonwealth Edison Company, Chicago, Ill.

A. J. Authenreith, Vice-President, Middle West Utilities Company, Chicago, Ill.

Edward J. Billings, Vice-President, Fuller-Lehigh Co., Fullerton, Pa.

John H. Buell, Manager of Operations, Oklahoma Power Company, Tulsa, Okla.

W. D. Collins, U. S. Geological Survey, Washington, D. C.

Charles Fox, Assistant Superintendent, Pennsylvania Water Company, Wilkinsburg, Pa.

C. P. Hoover, Chemist and Superintendent, Water and Sewage Department, Columbus Filter Plant, Columbus, O.

Nicholas S. Hill, Jr., President, Hackensack Water Company, Hackensack, N. J. and Consulting Engineer, New York, N. Y.

B. N. Randolph, Water Purifying Department, William B. Scaife and Sons Company, Oakmont, Pa.

Caleb M. Saville, Manager and Chief Engineer, Water Works, 53 North Beacon Street, Hartford, Conn.

Early last year a questionnaire was sent out to a large number of companies for information concerning these problems. The results of this inquiry indicated clearly that the treatment of municipal water supplies does not, in most cases, seriously affect its value for steam-making uses. There is a tendency, however, on the part of some municipal water treatment plant operators to lose sight of the industrial users' requirements, provided the sanitary requirements for the safe quality of the water are fulfilled. This is indicated by the increasing popularity of the procedure of adding sulphuric acid to water prior to alum, to increase coagulation, and to the inhibition of corrosion by the addition of lime to the filtered water. There is apparently a complete lack of knowledge by most engineers responsible for the treatment of water for industrial use, concerning these conditions. There are no data available as to the effect of such treatment on the cost of operation of privately owned water-purification plants.

Preliminary studies by the Committee indicates that these problems are of sufficient importance to be given consideration and require further study.

Considerable apathy apparently exists concerning the detrimental effect of trade waste on the operation and maintenance of power-plant equipment. Excepting in certain areas, particularly in Pittsburgh and some other districts, little effort has been made to cope with the problem.

One company situated in a highly developed industrial area has furnished the Committee with considerable detailed information concerning corrosion problems at its plant. A portion of their report is as follows:

> Our trouble has been due to acid coming from the pickling baths of a steel mill. This acid forms a hard oxide scale on the condenser tubes that seriously impairs our vacuum. This scale is so hard that the only effective method for its removal is the hydrochloric-acid-bath treatment.
>
> The acid in the water has eaten out our feed lines, impellers, strainers, etc. We are now just renewing completely the entire auxiliary feed lines. The old lines taken down were very badly eaten through, and all contained blisters and pockets.

The cost of cleaning the condensers at this plant is over $5000 yearly.

The effect of oil-refinery sludge on condenser operation is indicated in the following statement furnished by a large power company in the Middle West.

> The plant is located at a point below several oil refineries. These refineries discharge into the river certain oil sludges which carry acid. We have had to retube our condensers, and to date have not been able to determine whether the pitting or corrosion, which goes on in the condenser tubes, is due to the chlorine or alkaline character of the water or if it is assisted by the acid contained in the oil sludge, which latter substance deposits on the inside of the condenser tubes.

Replies from five companies using river water contaminated with oil sludge reported serious trouble from corroded condenser tubes and reduced vacuum as a result of sludge accumulation on the inside of the tubes. Two reported priming and foaming of boilers as a result of oil, although both companies used filters and softening plants to treat the feed water. At one plant the boiler-tube losses were excessive and these failures are traced directly to the presence of oil.

It is also quite apparent that domestic sewage, discharged into water courses used for cooling water in surface condensers, has a very detrimental effect. Several large companies on the Atlantic seaboard report that they can trace poor condenser efficiency and the majority of their condenser failures to this source.

The Committee submits this progress report merely to direct attention to the magnitude of the problem and makes the following recommendations:

1. Continuation of the Committee and expansion and coöperation with various state and governmental bureaus which are giving consideration to these problems.
2. Constructive research leading toward more efficient methods of treatment for the removal of trade waste from feedwater.
3. A comprehensive study of existing laws and ordinances relating to the prohibition of trade-waste pollution of streams used for feedwater or cooling-water purposes.

The Committee has established relations with the Trade Wastes Committee of the American Water Works Association and has arranged for an interchange of data relating to these problems.

WATER CONSUMPTION FOR VARIOUS PURPOSES IN TERMS OF DEPTH AND AREA[1]

By Charles H. Lee[2]

Rapid growth is characteristic of most American communities. This is especially true of those in industrial districts and in the rapidly developing western states, such as California. The normal population growth for the average American city is 20 to 30 per cent each decade, but for the average California city it is at least 50 per cent. Half of the cities of the state with 8000 or more population in 1920, experienced an increase of more than 75 per cent during the decade 1910 to 1920, and several of them doubled, and one even trebled in size.

These phenomenal growths bring added responsibility to the management of water work properties. For example, it is often found desirable to design and build major structures for the ultimate supply in order to meet the requirements of economy in cost. In semi-arid and arid regions where the supply is limited and there is probability of its use for other purposes, expenditures for water-rights and lands become necessary long in advance of actual need. It is quite common to find large cities looking ahead forty to fifty years in their water works construction programs, and, where located in regions of limited supply, the acquisition of lands and water-rights from seventy-five to one-hundred years in advance is not unusual.

The problem of determining the amount of water which will be required for future needs presents itself whenever any step is taken to provide additional water supply. It is the usual practice when estimating the requirements of an anticipated population to project forward the current rate of growth and apply to it per capita consumption based on present experience, as modified by probable changes in the character and amount of use. This method gives results sufficiently reliable for short periods and under ordinary conditions where domestic and public use predominate, or where expansion without radical change in the character of use is to be expected. A growing number of communities, however, show a tendency toward increase in demands of a character that cannot be readily determined on a basis of population and per capita consumption. Among such demands may be listed the use of water for industrial purposes, which often represents an important part of the total draft upon a water system. There is also the increased demand for water resulting from the tendency of modern cities to extend their borders beyond the built-up limits, thus adding much land devoted to commercial gardening, as well as tracts laid out as suburban residence property. In arid and semi-arid regions such areas require much water for irrigation. The amount of water required for either industrial or irrigation purposes bears no direct relation to population, and its use as a divisor is entirely arbitrary. Many of the instances of apparent abnormally high rate of consumption are due to relatively small population and large industrial or other special demand.

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[1] Presented before the California Section meeting, October 29, 1926.

[2] Consulting Hydraulic Engineer, San Francisco, California.

Perhaps the most complex of all problems of this character which water works officials and engineers are called upon to answer, is the future water requirement of metropolitan areas. Such areas will always be composed of distinctive units, some urban or suburban residential, some commercial or industrial, and some rural or recreational. Each will have different water requirements, the amount of which in many cases will be wholly unrelated to the number of individuals resident upon such areas. This problem has already come to the front in California in the Metropolitan Districts of Los Angeles and San Francisco-Oakland, and will later arise in the metropolitan areas which are beginning to surround San Diego and other rapidly growing cities. Recreational areas such as those about Monterey Bay and Santa Barbara also have this problem to meet.

There has thus arisen a definite need for some simple basis of estimating, other than population, which can be applied to all varieties of use and yet be related to some common factor. The problem has presented itself to the writer on several occasions and much thought had been given to it. As a solution, it is proposed to use area as the common factor instead of population, with equivalent depth of water delivered to the area as the measure of the requirement. This method has long been established in irrigation practice, the amount of water used being expressed as depth over the cropped area, the term "water requirement" or "duty of water" having come extensively into use in this connection. The area being served by a given water works system and the quantity of water delivered both being easily obtainable, it would seem feasible to determine the depth used per unit area, whether the use be for general municipal or for industrial or irrigation purposes. Analysis of water works statistics on this basis seems not only to yield results of value for use in estimating future consumption, but also to furnish a new and useful basis for comprehensive analysis and comparison of such statistics.

The mathematical relations of per capita consumption and depth can be very easily expressed in a formula which includes population density. If

Q = total annual water consumption in gallons
C = daily per capita consumption in gallons
A = area served in acres
P = population
p = population density
D = depth of water in feet per annum consumed upon service area

Then

$$D = \frac{Q}{A \times 325{,}850} = p\, C/890$$

and

$$C = 890\, D/p$$

In other words, the depth of water consumed per annum upon a given service area is directly proportional to both population density and per capita water consumption, while per capita consumption is directly proportional to depth of water consumed and inversely proportional to population density. By means of these equations, if population density is known, it is possible to convert per capita statistics into depth, and vice versa.

This paper gives the results of determinations of the depth of water used per acre per annum in general municipal service and in special services, for various American cities. It also illustrates a new method for analysis of water consumption data, which, it is believed, will be suggestive to both water works officials and the engineering profession. The writer desires to acknowledge and express his appreciation of the assistance furnished by various water works officials in California who were asked to furnish data. It is hoped that the paper will serve to bring forth additional information on this subject and help to stimulate the systematic reporting of the acreage of service areas.

WATER CONSUMPTION STATISTICS

The consumption of water from public water works systems, whether municipally or privately owned, includes both that used for domestic and public purposes, and for the needs of business and industry. It also includes loss and waste from distribution systems and service connections. In the average American city practically all domestic water is furnished from the public supply, and as the amount depends directly upon the number of people using water, it can be readily expressed on a per capita basis. An average for the United States under modern conditions is considered to be 30 to 35 gallons per capita per day, although where garden and lawn irrigation is practiced, as in California, this amount may be considerably exceeded. To this should be added public use for fire protection, sewer flushing, street sprinkling, parks, etc., varying from 5 to 10 gallons per capita per day in various cities. The minimum demand upon any water works system may thus be considered as from 35 to 45 gallons per capita for the population within the service area, plus the requirements for gardens and lawns in regions where irrigation is necessary.

The use of water for commercial and industrial purposes is in addition to this minimum and varies greatly in different cities, particularly that for industrial operations. This variation is due to the differences in manufacturing processes, the differing extent to which industries are established and the extent to which local sources are in use. In connection with the latter, the relative cost of water from the public system and from local sources, such as wells, is the important controlling factor. In cities where local sources are cheaply developed and pumping plants can be operated at small cost in conjunction with other equipment, the industrial demand upon a public water system is small. On the other hand, where the public supply is furnished for industrial use at a low rate, or local sources are not available, practically all such users within the city draw from the public supply. The percentage which commercial and industrial use bears to the total is therefore extremely variable, statistics indicating a range of from 15 to 65 per cent. These facts are all well known to water works men, but are so pertinent to the analysis of statistics which follows that emphasis seem desirable.

DEPTH OF WATER IN GENERAL MUNICIPAL SERVICE

Separate study has been made of the depth of water in general municipal service, and in special services such as domestic, com-

TABLE 1

Summary of water consumption data for 95 American cities, 80 per cent or more services metered

NUMBER	CITY	AREA SERVED*	POPULATION ‡		WATER CONSUMPTION			
			Total	Per acre	Total million gallons per day ‡	Per capita gallons per day	Per acre gallons per day	Per acre annual depth in feet
		acres						
1	Atlanta, Ga.	19,635	276,000	14.1	26	95	1,320	1.48
101	Altoona, Pa.	2,654	65,000	24.6	4,094	63	1,550	1.74
103	Albany, N. Y.	11,924	130,000	10.9	19,515	150	1,644	1.84
104	Akron, Ohio	15,990	208,435§	13.0	16,510	79	1,028	1.15
105	Beaumont, Texas	6,464	55,000	8.5	3,500	64	544	0.61
106	Binghampton, N. Y.	5,991	76,000	12.7	6,100	80	1,016	1.14
2	Boston, Mass.	27,635	788,000	28.5	87.7	114††	3,180	3.56
3	Brockton, Mass.	13,678	84,000	6.1	4.2	45††	307	0.34
107	Cicero, Ill.	3,678	70,000	19.0	6,500	93	1,768	1.98
108	Cedar Rapids, Iowa	7,805	52,000	6.7	4,475	86	576	0.65
109	Covington, Ky.	3,837	57,121§	14.9	5,500	96	1,430	1.60
110	Charlotte, N. C.	8,167	60,000	7.4	4,300	72	533	0.60
111	Canton, Ohio	8,029	102,000	12.8	13,000	127	1,625	1.82
112	Chester, Pa.	3,020	58,030§	19.2	7,500	129	2,480	2.78
113	Charleston, S. C.	2,873	67,957§	23.6	5,600	83	2,030	2.28
4	Chelsea, Mass.	1,191.6	47,000§	39.4	3.55	76	2,980	3.34
5	Cleveland, Ohio	43,929	1,074,000	24.4	151.2	143††	3,440	3.85
6	Cincinnati, Ohio	45,598	425,000	9.3	48.9	116††	1,070	1.20
7	Columbus, Ohio	16,475	270,000	16.4	23.2	87††	1,410	1.58
8	Dayton, Ohio	10,107	170,000	16.8	16.7	98	1,652	1.85
115	Des Moines, Iowa	33,597	140,000	4.2	11,818	85	357	0.40
116	Davenport, Iowa	10,393	61,000	5.9	4,800	79	466	0.52
117	Duluth, Minn.	39,917	100,000§	2.5	9,978	100	250	0.28
9	Detroit, Mich.	54,175	1,372,000	25.4	18.4	141††	3,400	3.81
10	Dallas, Texas	16,539	229,000	13.9	13	56	785	0.88
118	East Chicago, Ind.	6,396	50,000	7.8	5.500	110	860	0.96
119	Evansville, Ind.	5,577	85,264§	15.3	8.500	100	1.530	1.72
120	El Paso, Texas	8.640	82,500	9.5	7,300	88	836	0.94
11	East Bay Cities, Calif.	37,000†	498,000**	13.5	29.5**	59	796	0.89
12	Everett, Mass.	2,151	44,000	20.4	4.5	102	2,090	2.34
121	Flint, Mich.	18,140	130,000	7.2	14,000	108	778	0.87
122	Fort Worth, Texas	24,761	160,000	6.5	10,000	63	410	0.46
13	Fall River, Mass.	21,051	131,000	6.2	6.8	52††	323	0.36
14	Grand Rapids, Mich.	11,211	160,000	14.3	15.9	100††	1,420	1.59
123	Gary, Ind.	25,172	75.000	3.0	5,500	73	219	0.25
125	Houston, Texas	25,924	138,276§	5.3	12,000	87	461	0.52
126	Harrisburg, Pa.	3,861	82,849	22.0	11,403	138	3,040	3.41
127	Hoboken, N. J.	830	68,166§	82.0	7,500	110	9,025	10.12
15	Hartford, Conn.	10,163	182,000	17.9	16.2	85††	1,590	1.78
128	Jacksonville, Fla.	9,824	100,000§	10.2	10,000	100	1,020	1.14
129	Jackson, Mich.	5,653	52,000§	9.2	4,959	95	875	0.98
130	Kalamazoo, Mich.	5,285	54,900	10.4	4,393	80	832	0.93
132	Kansas City, Kan.	12,040	120,000	10.0	16,000	133	1,330	1.49
16	Kansas City, Mo.	37,395	384,000	10.3	48.3	134†+	1,290	1.45

Note: Data for cities numbered 1 to 46 from JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION, January 1926, pp. 1–21. Data for cities numbered 101 to 157 from 1925 and 1926 Municipal Index.

* Land area within political boundary, July 1, 1923, from Financial Statistics of Cities, U. S. Census Bureau—except as marked †.

† Service area.

‡ Population served and total water consumption as of 1924—except as marked § and **.

§ Population as of U. S. Census 1920.

** Data as of 1925.

†† Average of five years 1920–1924.

TABLE 1—*concluded*

NUMBER	CITY	AREA SERVED*	POPULATION ‡		WATER CONSUMPTION			
			Total	Per acre	Total million gallons per day ‡	Per capita gallons per day	Per acre gallons per day	Per acre annual depth in feet
		acres						
17	Los Angeles, Calif.	80,960†	1,100,000**	13.6	126.0**	109††	1,555	1.74
18	Lawrence, Mass.	4,317	103,000	24.0	4.6	46††	1,065	1.19
19	Lowell, Mass.	8,566	125,000	14.6	6.5	57††	765	0.86
133	Lansing, Mich.	7,082	74,000	10.4	6,500	88	916	1.03
134	Lincoln, Neb.	8,021	54,948§	6.8	5,333	99	673	0.76
135	Lakewood, Ohio	3,474	55,000	15.8	4,000	73	1,153	1.30
22	Malden, Mass.	3,252	53,000	16.3	2.86	54	880	0.98
21	Medford, Mass.	5,253	46,000	8.8	2.4	53	460	0.52
20	Mass. Metro. Dist.				124.1	97		
23	Milwaukee, Wis.	16,885	550,000	32.6	69.0	128††	4,090	4.58
24	Minneapolis, Minn.	31,834	417,000	13.1	42.8	102††	1,340	1.50
25	Manchester, N. H.	20,520	83,000	4.0	6.4	71††	312	0.35
26	Madison, Wis.	4,109	48,000	11.7	4.8	102††	1,168	1.31
27	Memphis, Tenn.	14,994	201,000	13.4	14	70	934	1.04
28	New Orleans, La.	113,920	412,000	3.6	45.4	110	398	0.44
29	Newark, N. J.	14,913	446,000	30.0	43.6	99††	2,920	3.25
30	New Bedford, Mass.	12,153	145,000	11.9	9.7	73††	800	0.90
136	New Britain, Conn.	8,519	61,000	7.2	6,000	98	706	0.79
138	Oak Park, Ill.	2,880	50,000	17.4	4,000	80	1,392	1.56
139	Omaha and Benson, Neb.	23,686	203.000	8.6	25,500	126	1,083	1.21
140	Pawtucket, R. I.	5,494	69,000	12.6	10,120	147	1,852	2.08
141	Patterson, N. J.	5,157	142,000	27.5	10,000	71	1,950	2.18
31	Providence, R. I.	11,410	284,000	24.9	23.6	82††	2,070	2.32
32	Quincy, Mass.	10,567	53,000	5.0	4.4	82	417	0.47
33	Richmond, Va.	15,360	180,000	11.7	20	108	1,287	1.44
34	Rochester, N. Y.	20,565	309,000	15.1	26.4	90††	1,285	1.44
142	Racine, Wis.	3,858	64,000	16.6	5,074	79	1,312	1.47
143	Springfield, Ill.	5,532	71,835	13.0	6,887	96	1,248	1.40
144	Syracuse, N. Y.	11,379	188,000	16.6	26,500	135	2,240	2.51
145	Scranton, Pa.	12,362	141,000	11.4	25,000	171	1,950	2.18
146	Spokane, Wash.	25,075	110,000	4.4	23,000	209	920	1.03
147	Sioux, Iowa	28,020	80,000	2.9	6,000	75	218	0.24
148	Shreveport, La.	8,486	65,000	7.7	5,100	79	608	0.68
36	Somerville, Mass.	2,518	101,000	40.1	7.8	77	3,100	3.47
35	St. Paul, Minn.	33,388	280,000	8.3	20.4	79††	610	0.68
37	Springfield, Mass.	20,286	151,000	7.5	13.5	91††	640	0.72
38	San Francisco, Calif.	16,170†	610,000	37.7	39.3	65††	2,450	2.74
39	Seattle, Wash.	43,840	378,000	8.6	40	105	915	1.02
40	Taunton, Mass.	30,266	37,000	1.2	3.6	99	119	0.13
41	Toledo, Ohio	18,440	283,000	15.4	29.0	104††	1,570	1.76
150	Terre Haute, Ind.	5,759	66,083§	11.4	5,000	76	867	0.97
151	Topeka, Kan.	5,460	60,000	11.0	7,000	117	1,290	1.45
152	Utica, N. Y.	13,404	105,000	7.8	9,500	91	710	0.80
154	Wilmington, Del.	4,495	117,727	26.2	13,638	116	3,040	3.41
156	Wachita Falls, Texas	6,788	55,000	8.1	4,500	82	665	0.74
42	Woonsocket, R. I.	5,532	51,000	9.2	3.1	54††	560	0.63
43	Waltham, Mass.	7,940	33,000	4.2	2.2	65††	277	0.31
44	Worcester, Mass.	23,782	192,000	8.0	16.3	86††	685	0.77
45	Washington, D. C.	39,680	486,000	12.2	64	132	1,610	1.80
46	Yonkers, N. Y.	12,880	110,000	8.5	13.4	113††	1,040	1.16
157	Youngstown, Ohio	16,224	145,000	9.0	12,500	86	773	0.87
Totals			17,829,091			8,972		
Average—95 cities						95		

mercial and industrial. For general service, the data available are limited to the total volume of water consumed for all purposes as contained in routine water works reports. The recent files of the Journal of the American Water Works Association and Municipal Index for 1925 and 1926 were extensively referred to in obtaining such information. Data for many California cities were also obtained by correspondence. It has never become customary to report service area acreage, and such information can only be obtained by direct contact with department officials. This has been done in the case of many California cities. For cities in other states which were not so obtained, the land area within municipal boundaries, as published in the latest annual reports of the United States Census Bureau, have been used.[3] This area does not in all cases represent water works service area, but it is believed to be sufficiently accurate for

TABLE 2

Summary of water consumption data for 8 American cities, 25 per cent or less services metered

NUMBER	CITY	AREA SERVED	POPULATION		WATER CONSUMPTION			
			Total	Per acre	Total million gallons per day	Per capita gallons per day	Per acre gallons per day	Per acre annual depth in feet
		acres						
1	Buffalo, N. Y.	24,890	550,000	22.1	119	213	4,780	5.35
2	Baltimore, Md.	27,634	797,000	28.8	105	132	3,800	4.25
3	Chicago, Ill.	124,604	3,015,000	24.2	806	275	6,470	7.25
4	Denver, Colo.	37,085	335,000	9.9	61	191	1,650	1.85
5	Indianapolis, Ind.	29,688	362,000	12.2	32.4	90	1,090	1.22
6	New York, N. Y.	191,360	6,015,000	31.5	789.2	129	4,120	4.61
7	Philadelphia, Pa.	81,920	1,914,000	23.3	323	168	3,950	4.43
8	St. Louis, Mo.	39,040	811,000	20.8	113.1	140	2,870	3.21
Totals			13,799,000			1,338		
Average						167		

Data from Journal of the American Water Works Association, January, 1926, pp. 1–21.

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[3] Financial Statistics of Cities, U. S. Census Bureau 1923, Table 1, and various bulletins.

TABLE 3

Summary of water consumption data for California cities—1924 and 1925

NUMBER	CITY	AREA SERVED*	POPULATION		WATER CONSUMPTION				PER CENT METERED
			Total	Per acre	Total million gallons per year	Per capita gallons per day	Per acre gallons per day	Per acre annual depth in feet	
		acres							
101	Alhambra	4,060	25,000	6.15	1,645	66	406	0.46	100
1	Belvedere Water Corporation	3,840	50,000	13.0	842	46	607	0.68	
2	East Bay Cities	37,000	498,000	13.5	10,766	59	796	0.89	100
102	Eureka	3,731	20,000	5.36	1,500	75	402	0.45	98
103	Fresno	5,432	72,000	13.3	17,500	244	3,246	3.64	8
3	Glendale	7,000	48,500	6.9	1,706	96	670	0.75	
104	Long Beach	9,309	140,000	15.05	17,000	121	1,820	2.04	100
4	Los Angeles†	80,960	1,100,000	13.6	45,996	109‡	1,555	1.74	97
5	Modesto	1,940	17,500	9.4	1,248	195	1,760	1.97	3
6	Marysville	400	7,500	18.8	408	149	2,790	3.12	0
7	Pasadena	12,000	87,736	7.3	3,372	105	770	0.86	100
8	Palo Alto§	1,020	7,731	7.6	347	123	928	1.04	100
9	Redwood City	1,500	8,500	5.7	190	61	348	0.39	100
10	Redlands	6,400	16,000	2.5	1,732	296	741	0.83	64
105	Riverside	25,088	30,000	1.16	5,750	190	220	0.25	90
106	San Bernardino	4,365	33,000	7.55	7,000	212	1,600	1.79	97
107	Santa Ana	5,573	33,000	5.91	7,000	212	1,254	1.41	100
108	Santa Barbara	8,051	29,600	3.68	5,000	169	622	0.70	93
109	Santa Cruz	5,702	15,000	2.63	4,000	266	700	0.79	75
11	Stockton	4,480	50,000	11.2	1,370	75	840	0.94	100
12	San Jose, Los Gatos, etc.	20,000	80,000	4.0	2,339	80	322	0.36	80
13	Sacramento	8,960	70,000	7.8	7,028	274	2,140	2.4	0
14	San Diego	44,800	106,047	2.4	4,894	126	304	0.34	100
15	San Mateo	4,800	10,500	2.2	263	68	152	0.17	91
16	Santa Rosa	1,339							
17	San Francisco	16,170	557,530	34.5	12,191	60	2,070	2.32	100
18	Vallejo	1,725	26,641	15.4	620	64	980	1.10	
Total			3,139,785			3,541			
Average						132			
Total—80 per cent or more metered			2,941,785			2,117			
Average—80 per cent or more metered						106			

Note: Data for cities numbered 1 to 18 obtained by correspondence. Data for cities numbered 101 to 109 obtained from Municipal Index 1925 and 1926.

* Service area for cities numbered 1 to 18; land area within political boundary for cities numbered 101 to 109.

† Excluding San Fernando Valley, Elysian and Griffith Parks and shoe string strip.

‡ Average for years 1920–1924.

§ Data for 1922.

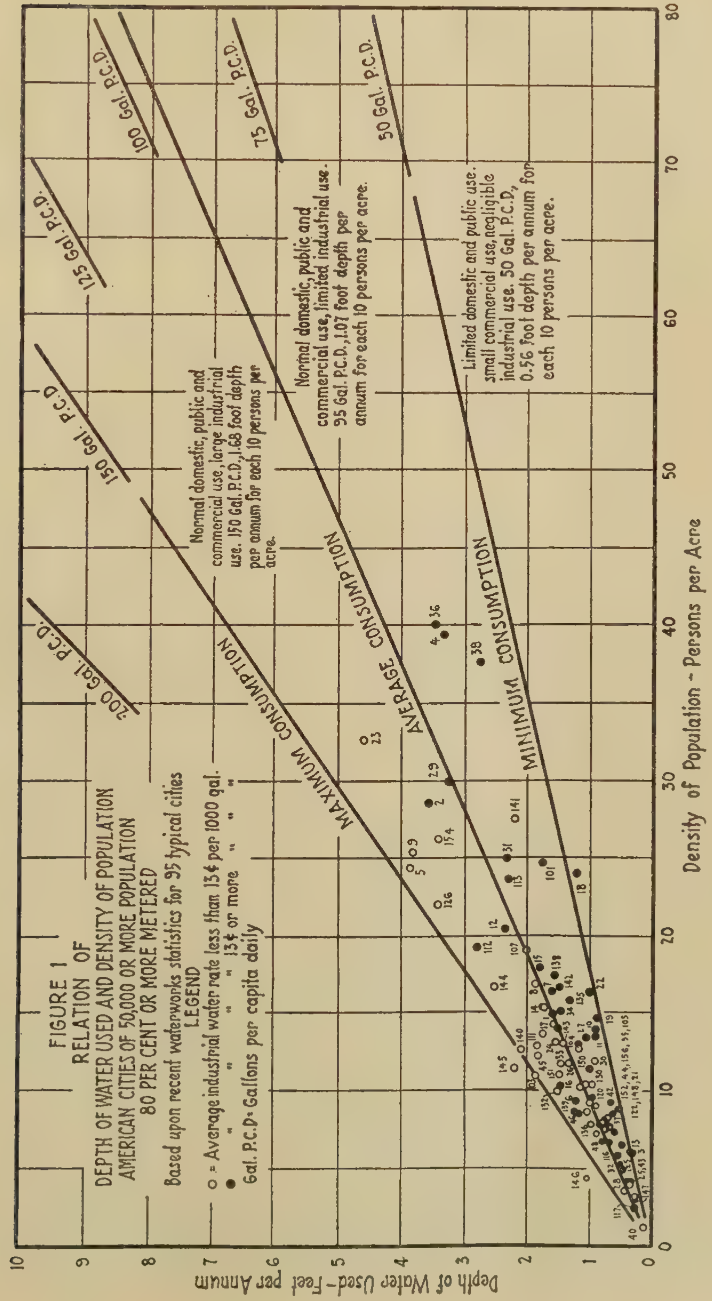

FIGURE 1
RELATION OF
DEPTH OF WATER USED AND DENSITY OF POPULATION
AMERICAN CITIES OF 50,000 OR MORE POPULATION
80 PER CENT OR MORE METERED

Based upon recent waterworks statistics for 95 typical cities the purposes of this paper. Data have been assembled for 103 typical American cities of 50,000 population and over (tables 1 and 2), and for 26 California cities with a population of 8000 or more (table 3). The data include area and population served, total water consumption, population density, per capita consumption, and acre consumption in gallons and feet depth.

Preliminary study of the data showed a wide range in rate of water consumption for different cities and suggested broad classifications for detailed study, as follows:

1. *Geographical.* American cities, 50,000 or more population, and California cities 8000 or more.
2. *Metering.* Cities 80 per cent or more metered, and those non-metered (25 per cent or less).
3. *Industrial water rates.* Cities 80 per cent or more metered with water rates for industrial use 13 cents or more per 1000 gallons for average amounts consumed monthly, and those with rates less than 13 cents.

The method of analysis followed has been graphical. Diagrams were prepared with depth of water served over the service area in feet per annum as the vertical scale, and density of population expressed as persons per acre for the horizontal. Each plotted point represents a city listed on tables 1, 2, or 3, the index number corresponding to that on the tables. Lines representing average, minimum, and maximum consumption have been drawn to conform with the plotted points. These lines pass through the zero point and their slope represents the increase of depth of water delivered for increase in population density. They can also be described in terms of per capita consumption, as is indicated by the form of the equation expressing the relation between depth, density and per capita consumption. The position of lines equivalent to various rates of per capita consumption in gallons per day have been indicated on the margin of all diagrams, thus facilitating the correlation of data when expressed either on a population or area basis. Separate diagrams were drawn for 103 American cities (figs. 1 and 2), and 26 California cities (fig. 3). The classification as to rates for metered cities has been indicated on each diagram by means of conventional signs.

American cities, metered

The total population served by the 95 typical water works in this class is 17,829,091. The per capita daily consumption varies from 46 to 209 gallons for the various cities, and averages 95 gallons. The range of depth is from 0.1 to 4.58 feet per annum, the latter being for cities of densest population (table 1). The arrangement of the plotted points on figure 1 although somewhat scattered, is definitely limited between the maximum and minimum lines, and clearly indicates the direct proportional relation between depth of water used and density of population. The average, minimum and maximum lines have the following values:

LINE	RATE OF DEPTH INCREASE PER ANNUM FOR EACH 10 PERSONS PER ACRE	DAILY PER CAPITA CONSUMPTION
	feet	*gallons*
Average	1.07	95
Minimum	0.56	50
Maximum	1.68	150

The spread of the plotted points on figure 1 is primarily due to the differences in the sum of commercial and industrial use and system losses. This is illustrated by the relative arrangement of plotted points with respect to the lines of minimum, average and maximum consumption. The lowest points, represented by the minimum line (50 gallons per capital per day), comprise the domestic, public and small commercial demand which is the foundation of the water works business. Points located much above this base line indicate that commercial and industrial demand or excessive system loss are appreciable, the extent being indicated by the distance of points above the minimum line, although the average line would probably be the base line for many cities, particularly where garden and lawn irrigation are practiced. It is a well recognized fact that the demand for water for industrial use is very sensitively influenced by the rates charged. An inspection of figure 1 shows that most of the points for cities where the industrial rate exceeds 13 cents per 1000 gallons lie below the average line, while points at which the rate is less than 13 cents lie above. With more detailed information regarding the relative amounts of water used for various purposes, a diagram of this type would furnish an unusually comprehensive background for the comparative study of water consumption statistics in various cities.

Information regarding the characteristics of various cities, whether residential, commercial or industrial, would also be useful. For example, the normal density of population of built-up residential

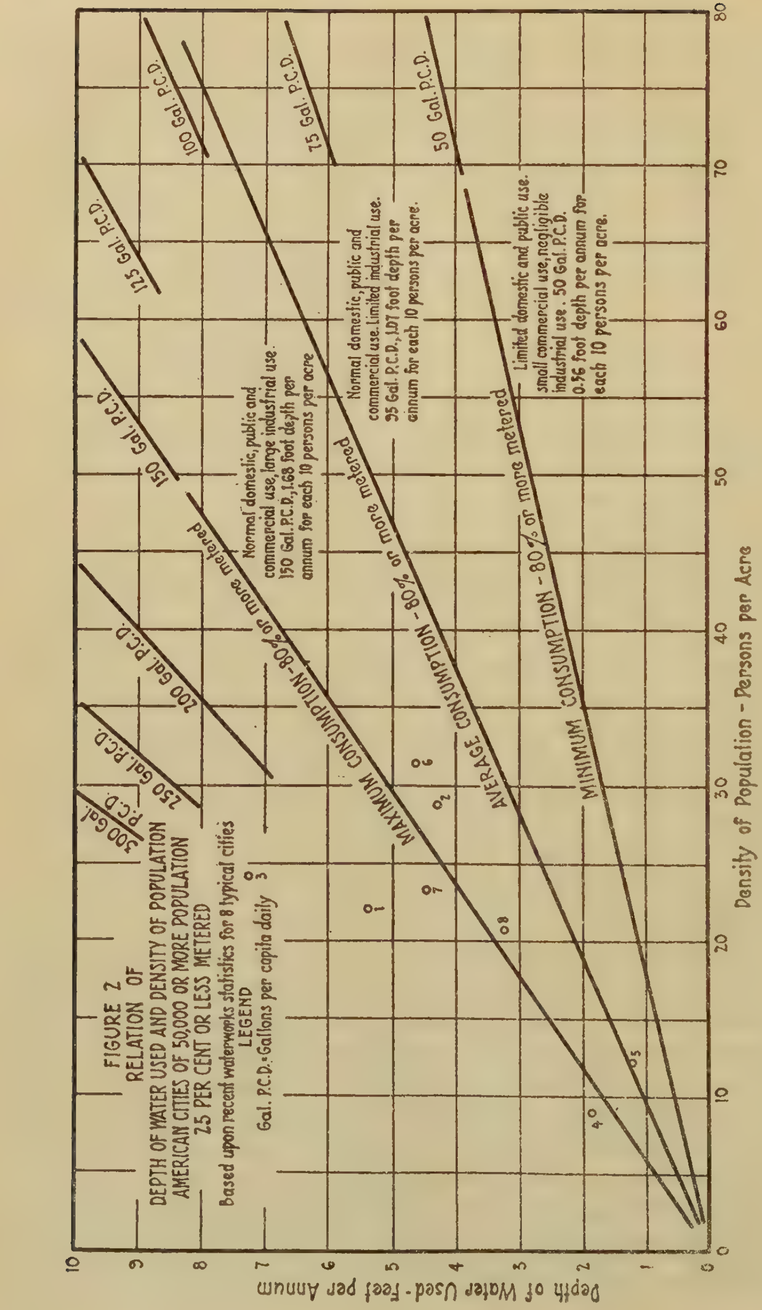

FIGURE 2
RELATION OF
DEPTH OF WATER USED AND DENSITY OF POPULATION
AMERICAN CITIES OF 50,000 OR MORE POPULATION
25 PER CENT OR LESS METERED
Based upon recent waterworks statistics for 8 typical cities
LEGEND
Gal. P.C.D. = Gallons per capita daily

cities whose population is largely housed in one-family dwellings, is from 8 to 10 persons per acre. This density corresponds on the diagram to a depth of approximately 1 foot per annum for average per capita water consumption. In communities with average water consumption, if the depth of water delivered exceeds 1 foot per annum, it may be concluded either that a considerable portion of the population is living above the first floor level in flats, apartments, hotels or tenement houses, or that the commercial and industrial demand is greater than average. Both factors often act jointly to increase the depth of delivery. Similarly, depths less than 1 foot indicate a partially built-up city or one in which industrial use is small. In a residential city it may also be indicative of the general absence of house gardens.

American cities, non-metered

The relative amount of water used by eight American cities of 50,000 or more population, with small per cent of metering (25 per cent or less) is shown by reference to table 2 and figure 2. The total population served is 13,799,000 and the average per capita consumption 167 gallons per day. The latter is 75 per cent greater than the average for cities 80 per cent or more metered (table 1). The points are so scattered that no attempt has been made to draw an average line. The average, minimum and maximum lines from figure 1 have been placed upon figure 2. The latter is instructive, both in its showing of excessive depths of water applied, and of high rates of per capita consumption. Loss and waste as well as low commercial and industrial rates are largely instrumental in producing these charactristics. As experience has often shown, the introduction of extensive metering tends to reduce excessive waste.

California cities, metered and non-metered

The determination of depth for California cities was made largely on the basis of service area, since, in many cases, considerable unused land was included within the municipal boundary. There being fewer points to plot, figure 3 includes both metered and non-metered cities.

The total population served in the 26 selected cities is 3,139,785, of which 2,941,785 are in cities 80 per cent or more metered. The average per capita consumption for twenty cities of the latter class is 106 gallons daily, which is 11 per cent greater than for the 95 American cities of 50,000 and over. The maximum is 217 gallons daily or 45 per cent greater. The difference is largely due to the greater use of water for lawns and gardens in the average California city. Average, minimum and maximum lines have been drawn on figure 3 with the following results:

LINE	RATE OF DEPTH INCREASE PER ANNUM FOR EACH 10 PERSONS PER ACRE	DAILY PER CAPITA CONSUMPTION
	feet	*gallons*
Average	1.19	106
Minimum	0.56	50
Maximum	2.44	217

The distribution of points is similar to that of figures 1 and 2, and the same general conclusions can be drawn. Rates for water for industrial use have the same influence upon water consumption as in American cities generally. The effect of meters in reducing loss and waste is also apparent. In addition to having a greater rate of water consumption, California cities differ from the average American city in having a relatively small industrial demand. The use of water for irrigation of lawns and gardens appears to be great enough to more than offset the deficiency in industrial demand. This fact points to a material increase in future demand in California cities which may be fortunate enough to have rates low enough to attract industry.

A tabulated summary of all data compiled for American and California cities, based on the curves drawn on figures 1 and 3, has been prepared herewith as tables 4 and 5. These tables set forth the depth of water used in general municipal service in feet per annum for minimum, average and maximum consumption, and for densities of population from 5 to 50 per acre. Their field of application is in estimating future water consumption in self-contained community units. The data do not apply, however, to special services and segregated areas, such as strictly residential, industrial or agricultural. For such, the results of special tests are necessary.

DEPTH OF WATER IN SPECIAL SERVICES

Water works reports are usually lacking in information regarding the use of water for special purposes, such as domestic, commercial or

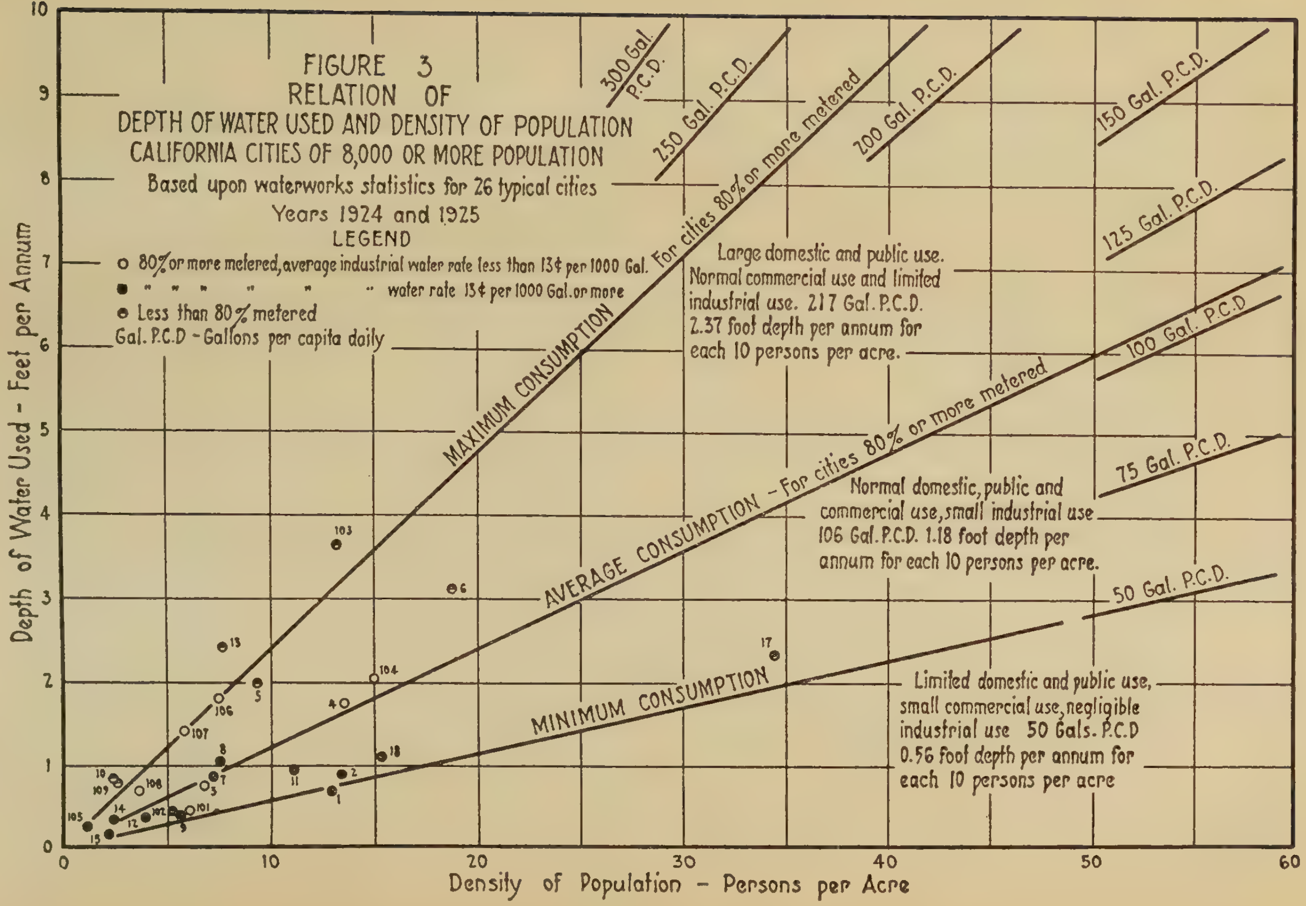

FIGURE 3
RELATION OF
DEPTH OF WATER USED AND DENSITY OF POPULATION
CALIFORNIA CITIES OF 8,000 OR MORE POPULATION
Based upon waterworks statistics for 26 typical cities
Years 1924 and 1925

industrial. The rate of per capita consumption, as determined from statistics in such reports, is a composite made up of all varieties of use, and throws but little light upon any one type. The only available source for such data are reports of special tests. With the increased tendency toward zoning, as stimulated both by city and

TABLE 4

Average water consumption for typical American cities, 80 per cent or more metered

Expressed as depth of water over service area

DENSITY OF POPULATION	DEPTH OF WATER OVER SERVICE AREA—FEET PER ANNUM		
	Minimum consumption 50 gallons per capita	Average consumption 95 gallons per capita	Maximum consumption 150 gallons per capita
5	0.28	0.54	0.84
10	0.56	1.07	1.68
15	0.85	1.60	2.53
20	1.12	2.15	3.37
25	1.40	2.67	4.22
30	1.68	3.20	5.05
35	1.97	3.73	5.90
40	2.25	4.26	6.75
45	2.53	4.80	7.59
50	2.81	5.34	8.44

Data based upon curves drawn for 95 typical cities (fig. 1).

TABLE 5

Average water consumption for typical California cities 80 per cent or more metered

Expressed as depth of water over service area

DENSITY OF POPULATION	DEPTH OF WATER OVER SERVICE AREA—FEET PER ANNUM		
	Minimum consumption 50 gallons per capita	Average consumption 106 gallons per capita	Maximum consumption 217 gallons per capita
5	0.28	0.58	1.18
10	0.56	1.16	2.37
15	0.84	1.78	3.55
20	1.12	2.37	4.74
25	1.40	2.97	5.92
30	1.68	3.56	7.10
35	1.96	4.16	8.29
40	2.23	4.76	9.48

Data based upon curves drawn for 20 typical cities (fig. 3).

regional planning programs, more detailed information is coming to be in greater demand. The following specific data for consumption in California cities have been obtained from various sources, and is presented in the hope that it will stimulate the more systematic collection and publication of such information. In addition to other uses, such data would be very valuable in distribution system design.

TABLE 6

Depth of water in domestic use

CHARACTER OF DOMESTIC USE	CITY	AUTHORITY	DEPTH OF WATER USED IN FEET PER ANNUM
First class residential—large improved estates	Los Angeles	Bureau of Water Works and Supply	2.14
First class residential—large improved estates	Atherton	Charles H. Lee	2.10
First class residential—large lots with lawns and gardens	Los Angeles	Bureau of Water Works and Supply	1.90
Second class residential—small lots with lawns and gardens	Los Angeles	Bureau of Water Works and Supply	1.61
Third class residential—small lots, many with gardens	Los Angeles	Bureau of Water Works and Supply	1.35
Third class residential—small lots, few gardens	Belvedere, Laguna and San Antonio Twp. adjacent to N. E. Limits City of Los Angeles	Belvedere Water Corporation	0.68

Domestic use

Domestic use includes that necessary for human needs, such as drinking, cooking and washing. To this should be added the water used for irrigation of gardens and lawns, where such is necessitated by local climatic conditions. Table 6 indicates the amount of water delivered for this purpose, as shown by various tests. The influence of lawns and gardens in increasing the rate of domestic consumption is quite apparent. First-class residential areas, for example, with large improved estates consume three times the quantity of water used on areas where the demand is limited to strictly human needs. It is to be noted in using these data that, with the possible exception of the area served by the Belvedere Water Corporation, the data apply to fully built-up districts. The service area as reported for a whole city, on the other hand, would ordinarily include isolated vacant lots and other small non-consuming areas.

Commercial and industrial use

The term "commercial use", as generally applied, includes not only the strictly commercial use of water in hotels, stores, office buildings and apartment houses, but also industrial use by manufacturing plants, railroads, sugar refineries, laundries, etc. Commercial use is usually small relative to total consumption, and is constant in amount. Industrial use, however, may be very large in amount and varies with business conditions and the relative cost of water from the public system and from privately developed sources. Considered from the standpoint of area, the two services seldom overlap. With haphazard growth, commercial and industrial plants are seldom to be found mingled, and modern zoning practice tends to emphasize the separation. For purposes of estimating future water requirements, it has been found very useful to have the two services considered separately, and they will be hereafter so considered in this paper.

The amount of water used in commercial service, although a small proportion of total consumption, is large when expressed as depth upon the area to which the water is actually delivered. This is illustrated by a test made by the Bureau of Water Works and Supply of the City of Los Angeles for the consumption in the congested business district bounded as follows:

> Hill Street from First to Fifth Street, Fifth Street to Grand Avenue, Grand Avenue to Sixth, Sixth Street to Figueroa, Figueroa Street to Ninth, Ninth Street to Los Angeles, Los Angeles Street to First, and First Street to Hill.

The water delivered to this area of 324 acres in September 1923 was equivalent to a depth of 2.16 feet. As the rate of delivery to this area is practically constant throughout the year, the annual depth may be considered as 24.36 feet. Spread over the whole city service area this amounts to but 0.10 feet in depth, as compared with the total annual depth for all purposes of 1.74 feet.

The amount delivered for industrial purposes in the typical area of 183 acres bounded by seventh, Sacramento and Alameda Streets, and Los Angeles River, was also measured. This area received during the period July 1, 1923, to June 30, 1924, a depth of 1.67 feet of water. This quantity is very small in comparison with the amount of water consumed in the industrial districts of many eastern manufacturing centers. Inspection of figures 1 and 2 indicate that, for the larger cities, the water used in industrial purposes, if spread over the whole city service area, exceeds 1.50 feet. As industrial plants occupy a minor portion (less than one-fourth) of even the most distinctively industrial cities, it is to be inferred that the annual depth consumed on the area actually devoted to industrial use may be as great as 5 or 6 feet, and may even exceed this figure in the case of special industries using large quantities of water for washing processes. Data are very meagre on this subject, and, with the prospective industrial growth in many western cities, special effort to obtain such information for different types of industry would be well worth while.

DUTY OF WATER IN IRRIGATION SERVICE

It frequently occurs in western cities that irrigated areas are included within the municipal boundaries. Such lands may either be temporarily used for commercial agriculture in the raising of berries, garden truck, or flowers, or may be more permanently devoted to residential or recreational purposes. Golf courses and public parks and playgrounds may be included within the latter. Often as a city expands it encroaches upon irrigated farm land devoted to the growing of orchards or general crops. The question thus arises in water works practice as to the quantity of water used by such land under irrigation, as compared with the needs of the same land under suburban or urban conditions. The subject of the use of water in irrigation is beyond the scope of this paper, but for comparative purposes certain general data may not be out of order.

The amount of water required in irrigation depends upon many factors, among which may be mentioned climatic conditions, including temperature and precipitation, soils and crops. For lands already under irrigation the stage of economic development of the region and the character of the people are important factors. Recent comprehensive studies made by the State Engineer show that in California the amount of water actually used in various parts of the state for irrigation of general crops varies in depth from 1.14 feet to 3.88 feet per annum, and that a corresponding desirable duty would vary from

1.25 feet to 3.00 feet.[4] These figures are for water delivered to the land, and do not include the large losses in transmission often amounting to as much again as that delivered.

Table 7 compiled from the State Engineer's report gives the average measured use and desirable duty of water in the vicinity of the larger cities of California.

TABLE 7

Average measured use and duty of water in vicinity of large cities of California

CITY	MEASURED USE DEPTH IN FEET	DESIRABLE USE (DUTY) DEPTH IN FEET
San Diego	1.26	1.25
Los Angeles	1.62	1.75
Bakersfield	2.24	2.00
Fresno	2.24	2.00
Stockton	2.24	2.00
Sacramento	3.88	2.25
Santa Barbara	2.43	1.5
Santa Cruz	1.42	1.5
Monterey	1.82	1.75
San Jose	1.42	1.50
San Francisco	1.42	1.50
East Bay Cities	1.42	1.50
Eureka	1.52	1.25

TABLE 8

Use of water for irrigation in San Fernando Valley, City of Los Angeles, California

YEAR	ROTATED CROP ACREAGE, ACRES	NET CROP ACREAGE, ACRES	ROTATED CROP DUTY, DEPTH IN FEET	NET CROP DUTY, DEPTH IN FEET
1919	69,000		1.06	
1920	71,000		1.09	
1921	63,300	55,000	1.20	1.38
1922	56,278		1.30	
1923	58,410	52,410	1.43	1.60
1924	60,917	51,723	1.02	1.20
Average			1.18	1.39

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[4] Irrigation Requirements of California Lands, Bul. No. 6, State of California, Department of Public Works, 1923.

It is to be recognized, however, that the above values represent broad averages and that considerable local variation from them is to be expected. Taking up more detailed data, the irrigation use for general crops in the San Fernando Valley within the boundary of the City of Los Angeles, as served from the City's irrigation system, is reported in table 8 by the Bureau of Water Works and Supply.

More than half the acreage in the San Fernando is planted to crops requiring but little irrigation, such as beans, walnuts, etc. Where a considerable proportion of the crop area is in alfalfa, as in the San Joaquin and Imperial Valleys, greater amounts are used, varying from 2 to 3 feet depth per annum delivered at the land.

The question as to the relative quantity of water which will be required when an irrigated area is annexed to a growing city, with the prospect of the land being subdivided and used for other purposes, is one of growing importance. The past experience at Los Angeles has been that, as irrigated lands are subdivided and become residential in character, with one-family houses surrounded by lawns and gardens, the water requirement remains unchanged or at least does not exceed that for irrigation. The data assembled in this paper confirm this experience and indicate that the same rule would hold for residential cities generally in California, including those in the region of San Francisco Bay. The rule does not hold, however, for cities with population density exceeding 9 or 10 per acre. In such communities the population has begun to live on more than one floor level, apartment houses and flats are in evidence and commercial activities and industries have become established with greater demands upon the water supply.

San Francisco, for example, with a population density of 37.7 persons per acre, uses a depth of water nearly twice the local irrigation use (tables 1 and 7). Long Beach, with a density of 15, uses nearly 25 per cent more water in depth than is used in local irrigation. Even Los Angeles, which, during the past few years has reached a population density greater than 10 per acre, is beginning to exceed the local irrigation requirement. For residential cities in California the rule will probably continue to hold, but as such cities become more metropolitan in character, and industries are established, there will undoubtedly be a change. There are thus very definite limits within which urban water requirements can be considered as acre for acre identical with that for irrigation.

CONCLUSIONS

1. The analysis of water consumption data on the basis of service area is feasible and is more logical for all the varied types of service rendered by a modern water works than is population.

2. The depth of water delivered to the service area in general municipal service varies directly as the density of population. Variation from the average is largely due to the influence of industrial demand or excessive loss and waste. The values for different cities vary from 0.1 to 4.58 feet per annum.

3. In domestic service alone the depth seldom exceeds 2.1 feet per annum, including the irrigation of large beautified estates. For human needs alone the depth is less than 1 foot.

4. Industrial demand requires a maximum of possibly 5 or 6 feet depth per annum, although data are lacking for a definite determination.

5. In commercial districts the demand may run as high as 24 feet per annum.

6. The duty of water in irrigation varies from 1.25 to 4.58 feet per annum.

7. Graphical analysis of water consumption data on the basis of depth of water and density of population offers a method for comparative study which is simple and comprehensive.

8. "Service area acreage" should be added to the items listed in The Manual of Water Works Practice, as the least which a water works system should have (pp. 433–4).

9. The making of special tests of the depth of water delivered in various types of water works service should be encouraged.

THE USE OF THE DORR CLARIFIER IN WATER TREATMENT[1]

By John D. Fleming[2]

The introduction of the Dorr Clarifier to water treatment is so recent that I may assume some of you are unfamiliar with the apparatus, so I shall give a brief history and description of the mechanism. I would characterize it as a device for the continuous separation of solids from a suspending liquid, the elimination of a large part of the liquid trapped by the settling solids, and the continuous removal from the containing basin or tank, of the solids thus thickened. It was invented and patented in about 1910 by J. B. N. Dorr, a mining engineer, as a device for the dewatering of gold ores undergoing cyanidation. From this metallurgical origin in the West, application of the same principle was made in the East, first to the chemical industries, then to the handling of domestic sewage and trade wastes. Only within the last five years has the Dorr Clarifier entered the field of water treatment, first in water softening, and just now one might say, in preliminary sedimentation of turbid waters, the Kansas City plant being the first designed for this purpose.

Before describing the Dorr Clarifier, I want to comment on its name. A rose may smell as sweet by any other name, but in water treatment a Dorr Clarifier by some other appellation would not give rise to the confusion as to its purpose, which, I believe, often exists in the minds of water works engineers. The names "Thickener," and "Classifier," as applied in the metallurgical industries, are indeed descriptive, but the use of the name "Clarifier" in the sanitary engineering field is not defensible, nor is it descriptive. I cannot refrain from insisting that the name Clarifier is misleading, because one at once associates an influence of the mechanism on the water undergoing treatment and overflowing from the basin, whereas in reality, the influence is exerted on the mud being discharged at the bottom of the basin. Only by reason of the fact that, through the continuous discharge of mud from the basin, the mud line can be held below a predetermined elevation, and thus a maximum detention maintaned continuously, can it be fairly said that the character of the water is affected by the Dorr Clarifier. Since this result is secondary, and the primary interest lies in the disposal of the mud, I would suggest that Dorr "Basin Cleaner," "Sludge Remover" or some other such name would be much more suitable.

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[1] Presented before the Iowa Section meeting, November 4, 1926.

[2] Assistant Chemical Engineer, Water Department, St. Louis, Mo.

The Dorr mechanism in its simplest form consists of a central vertical drive shaft supported by a superstructure, and carrying at its lower end one or more radial arms, on which are mounted a series of parallel rakes. These rakes are set in vertical planes at angles of 45° with the radial arms, the angle being read in the first quadrant from the top aspect. The sweeps of adjacent rakes overlap by a few inches, so that as the mechanism is slowly rotated in clockwise manner, each rake, sweeping over the shallow conical basin bottom, slips the encountered mud towards the center of the basin, the furrows thus swept up coming within the sweeps of the following rakes, which in turn, sweep the mud still closer the center, and so on around, until the innermost rake drops its sweepings into a sharp conical hopper, from which the mud is discharged in a continuous stream, either by gravity or pumping. The interesting thing about this sweeping up of the mud from the floor of the basin is, that, contrary to what might be expected, subsidence is thereby aided, not disturbed. No disturbance is given because the motion of the rakes is extremely slow,—one revolution in three to forty minutes, depending on the size and duty. The aid to subsidence arises by reason of the tumbling action of the rakes on the mud, whereby the watery envelopes over the mud particles are broken, and the water thus freed escapes with added facility given by numerous fine channels in the sludge, these channels likewise being caused by the cutting action of the rakes. Both phases of this theory of thickening are susceptible to laboratory demonstration and proof, but regardless of the theories involved, thickening is a fact, for we have by a laboratory raking apparatus, thickened mud in seventy-two hours to a density not attained in twenty-one days of undisturbed settling.

Clarifiers are made to operate in round or square basins, in units from 9 to 225 feet in diameter, the radial arms of the larger units, e.g., at Kansas City being pulled around by peripheral traction instead of driven from a central shaft. The one being studied by the St. Louis Water Works is an experimental unit, 25 feet in diameter, shaft driven, and operates in a round tank 7 feet deep. The unit has been loaned us by the Dorr Company, together with accessory tanks and apparatus for supplying chemicals if desired. The equipment was set up at the present Chain of Rocks plant, in a place conveniently located with reference to the raw water supply from the service pumps, sewers, and the chemical laboratory. A 15-foot square tank was placed 8 feet to the north of the clarifier unit, with an eight channel mixing chamber 120 feet long, between the two. Agitator tanks for supplying milk of lime and iron sulphate solution by gravity feed, were housed just to the east of the mixing chamber. Raw water was supplied through a 6-inch pipe, and measured by direct discharge through bronze orifice plates having sharp edges, the head on the orifice being maintained by a slow overflow from a 3-inch piezometer tube. Arrangements were made for the direct discharge of the raw water into the north side of the square tank, the north end of the mixing chamber, and the filling box of the clarifier. Means of very accurately feeding lime and iron were also provided. The

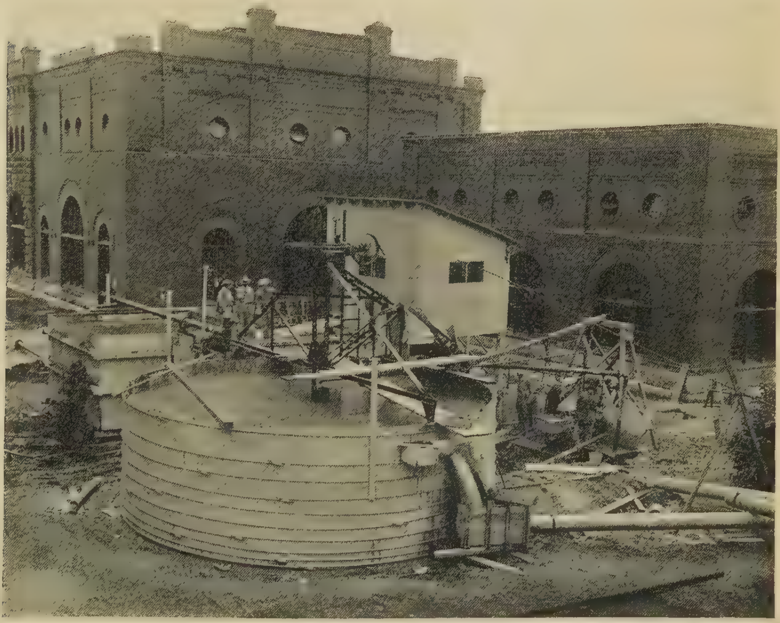

FIG. 1. GENERAL VIEW OF EXPERIMENTAL PLANT AT ST. LOUIS WATER WORKS

purpose of this rather elaborate set-up was to study the performance of the clarifier when handling raw water sludge, sludge from softened raw water, and finally, the sludge from water which had been first settled by plain sedimentation, and then softened. It was hoped that, incidentally, some very valuable large scale data would be obtained, corroborative of the writer's laboratory findings, on the chemical savings to be expected from preliminary sedimentation of Mississippi and Missouri river waters.

This was a fairly ambitious program of study, but was doomed to failure of attainment, in part, by the intervention of mother nature. No sooner had operations started, when the suspended solids of the raw water dropped in the course of a week, from 1000 parts per million to 200, and remained there for almost six weeks. The deposition of sludge from such water, handled by any of the three methods of operation outlined above, is so extremely slow, that the study of continuous sludge discharge is rendered practically impossible, as anyone will easily discover by a few simple arithmetic calculations, and a consideration of the natural limitations of models.

Thus thwarted, resort was made to the supplying of foreign or artificial sludge, so to speak. Advantage was taken of the cleaning of our primary settling basin about to be undertaken at this time, and mud from the drained basin was put into the clarifier by means of a jet pump. This sludge, of course, was that from softened raw water, and, while not a fully satisfactory substitute for sludge built up right in the clarifier, it was possible therewith to get some fairly acceptable data on the possibilities of sludge discharge.

To study a sludge approximating that from raw water, we then rapidly discharged the coagulated raw water sludge which had been put into the clarifier, and recirculated it with a jet pump in such a manner as to disturb the settling sufficiently to allow the coagulant and fine clay present to pass out of the tank in the overflow. This was continued until the sludge on dilution showed no evidence of coagulant in its makeup. Furthermore, fine sand from the river bank and some coarse sand from the plant grit chamber was added directly to the tank. A sludge was formed in this way, which, in all probability, was much more difficult to handle than a genuine raw water sludge. The regulation of discharge is accomplished by varying the size of the orifice and adjusting its elevation. This latter variation is obtained by using a riser pipe connected flexibly to the horizontal part of the sludge line at an angle of 45°, so as to give the riser a swivel action. Measurements and calculations have been made to determine the friction head in the discharge line for orifices varying from $\frac{5}{16}$ to $1\frac{1}{4}$ inch, with discharge rates varying from 730 to 6000 pounds of sludge per hour, the solids ranging between 25 and 58 per cent by weight.

None of the detailed data obtained is to be submitted in this report, but it may be stated in a general way that, by this swivel and orifice method, a continuous gravity discharge of raw and coagulated raw water sludges can be had from the Dorr Clarifier, using a smooth steel pipe, free from all shoulders such as bell joints, valve seats and sharp bends, and provided further, that the rate of discharge be suitable to the density of the sludge. These provisos indicate the necessity of much attention to details of construction, and a rather complete analytical knowledge of the formation, as well as the discharge of the sludge. By careful supervision of this kind, I have every reason to believe that the Dorr "Basin Cleaner," as I choose to call it, will thus continually hold the mud line in a basin to a predetermined elevation, with an actual water loss of less than 0.2 per cent for each 1000 parts per million suspended solids in the feed water.

The study of sludge removal by diaphragm pump is about to be made. It seems quite likely that, by pumping, a very much simpler regulation of flow can be obtained, and the economical handling of very dense sludges, probably 40 to 50 per cent solids, is anticipated.

CENTRIFUGALLY CAST PIPE[1]

ROBERT B. MORSE:[2] Our district, which covers the suburban areas in Maryland near the District of Columbia boundary, has purchased approximately 90 miles of deLavaud pipe and most of this has been laid already. All sizes of deLavaud pipe, from 6 to 16 inches, have been installed, and we now have a 20-inch line under construction. Up to this time, practically all of the pipe has been laid by our own forces, but we have two large construction contracts, involving the use of deLavaud pipe, going on at present.

Our experience with this kind of pipe has been somewhat similar to that of Mr. S. H. Taylor. No difficulty has been experienced in handling and cutting, except in the case of three pieces of 12-inch pipe, distributed in one street, which cracked while being cut. We have had some trouble, however, with pipe that has split after being laid in line, this taking place in some cases a long time after the main had been placed in service. Most of the early breaks occurred in connection with pipe from several shipments that bore evidence of poor loading or rough treatment in transit; but later mishaps, somewhat less, though disturbingly, frequent, cannot be accounted for so easily. Pipe of 12-inch diameter is the worst offender in our system.

Our men find some difficulty in using fittings with deLavaud pipe. Although the fittings are supposed to be ring-calipered at the foundry, some of their spigot-ends cannot be inserted in the deLavaud bell. The deLavaud spigot, on the other hand, having no bead, has allowed the jointing material (leadite, in our practice) to pass by the braided gasket, in some instances, and enter the fitting at the bell-end. We have eliminated this trouble by using loose unoiled jute for the bells of fittings.

The workmen on our lines like deLavaud pipe much better than sand-cast, on account of its light weight and the facility with which it may be centered. It must be handled with reasonable care, however.

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[1] Discussion presented before the Buffalo Convention, June 11, 1926.

[2] Chief Engineer, Washington Surburban Sanitary District, Hyattsville, Md.

We take bids on both sand-cast and deLavaud pipe on the linear foot basis and have found that the delivered cost of the latter has been from 5 to 10 per cent less than of the former.

Charles W. Sherman:[3] In some ways my experience with centrifugally cast pipe is not quite as intimate as that of those who have taken part in the discussion up to the present time. I am Chairman of the Board of Water Commissioners in the town in which I reside, Belmont, Mass., and have not personally handled the pipe like the superintendent who has put it in the ground, and who has to make repairs if any are to be made. I have also been consulting engineer to towns which have laid some of this pipe, and again my experience with it has ended when the pipe was laid. I have had something to do with 10 miles or so of deLavaud pipe up to 14 inches in size, which has gone into the ground, and as much more of 6- to 16-inch which is going into the ground this year.

My experience has been entirely favorable.

My first order was an experimental one. I think I bought fifty lengths of six inch pipe, to see how it would work out, and told the superintendent to use reasonable care, but nevertheless to find out what the pipe was good for. His report was favorable; and since then in my own town, we have bought nothing else, because we found that we could save money and get satisfactory pipe. I have no specific figures, but I am confident it has cost us less to handle this pipe and put it into the ground than for the sand cast pipe. We have not dropped the pipe into the trench as described by some of the previous speakers. We use a tripod derrick, and we have had no breakages. There have been breakages in transportation by rail and by trucks to the job, about the same as with the sand cast pipe.

As for cutting, once the men learned how to do it, we found no particular trouble. Light blows are essential, as was noted by several of the speakers. It is very easy to crack the pipe by striking too heavy blows, and a crack is likely to be a longitudinal crack, spoiling quite a piece of pipe. As to tapping, I have heard objections by some who had no experience with the pipe, that the wall was too thin. We get threads enough, and they are beautiful threads. My superintendent assures me that he can screw a corporation cock in by hand and make a tight joint.

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[3] Consulting Engineer, Metcalf and Eddy, Boston, Mass.

Some of the other advantages are worthy of reiteration. We get a pipe slightly larger than the nominal diameter, which means increased carrying capacity. If tuberculation occurs, it may continue for a time before we even get down to the carrying capacity of a new pipe of the nominal size. Experience has been too short to prove it, but I am inclined to believe that the dense iron which goes into this pipe will tuberculate less rapidly than the sand cast pipe. In most of the centrifugal pipe the interior surface is very smooth, more so than the ordinary sand cast pipe, which would mean a better coefficient of carrying capacity when new. In my own experience I have found the interior surface to be somewhat less satisfactory with the larger sizes. The 6-inch pipe was almost as smooth as glass; the 8-inch not quite so good; the 12-inch was not so smooth and the 14-inch was still less smooth. The 16-inch is cement lined, anyway, so we do not know what the interior surface of the iron is like.

D. A. Heffernan:[4] This year for the first time our purchase of cast iron pipe for mains consisted entirely of deLavaud, the pipe being lined with cement. Just previous to leaving home for this convention we had completed a 10-inch line, 2300 feet long. Inasmuch as it was the first time that we had used centrifugally cast pipe, I gave an unusual amount of personal supervision to the work.

In the first place I made certain that the pipe was unloaded carefully. I might mention in passing that we unload all our own pipe and deliver it at or near the jobs on which it is to be used. We did not run up against one length of pipe that was damaged. On all our main work we test the pipe line by water pressure before the pipe is covered. I will admit that I was perhaps a little nervous about the pipe at first, but I can truthfully say that, if ordinary care is given in its handling, there is no danger of the pipe cracking or breaking.

For the information of some who may be considering the use of this pipe I will tell them that, in cutting it, the use of a dog chisel and heavy blows of the hammer are liable to cause damage or, at least, result in a very ragged cut. The hammer and dog chisel may be used with very good success if light blows are struck. I have also cut this pipe with a wheel cutter and had very good success with it.

I understand that there are several cities and towns in my vicinity where cement-lined pipe is being used but where fittings are unlined. My belief is that if a community intends to use cement-lined pipe it should go all the way and use cement-lined fittings. I consider this the best practice because we ran up against the same experience with cement-lined wrought iron pipe which we used in our services. At first, these fittings were unlined and we experienced trouble where the pipes were joined. Later on we began to line all our fittings with lead and have overcome our earlier worries, and, I believe, have now a very long lived service.

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[4] Superintendent, Water Department, Milton, Mass.

I know of two concerns who are equipped to deliver fittings with a cement lining and I am sure they both will give good service.

MR. CRANE (St. Petersburg): We have had experience in putting in 6 to 7 miles of deLavaud pipe, 6 to 8 inches in size. We have had some hardness, some brittleness, but generally it has been along the line spoken of, and I would say that now the city of St. Petersburg has entered a contract for between 60 and 70 miles of this same pipe, and we expect to get as good service in that as in previous lots.

WM. W. BRUSH:[5] I should like to inquire whether, in tapping, any of you gentlemen, who have used the pipe, have reduced the maximum size of the tap that you would put in a given sized pipe? Presumably the usual sized tap will satisfactorily go in even the thinnest walled pipe that you have, but have you reduced the maximum sized tap that you would put in any given sized pipe, on account of the thinner wall?

MR. HAINES: We do not make any difference; we use the Muller machine and tap them as they come. We cannot see that it is necessary to make any change in the size of the tap. We get a good thread and a tight joint and everything seems to be satisfactory.

STEPHEN H. TAYLOR:[6] We have not changed our practice at all. I think the metal is so much more dense and strong that we get a very much better thread, so there is no reason for making a change.

ROBERT B. MORSE:[2] We have made no change, either.

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[5] Deputy Chief Engineer, Department Water Supply, Gas and Electricity, Municipal Building, New York, N. Y.

[6] Superintendent, Water Works, New Bedford, Mass.

William J. Willson:[7] We have not got very much of that pipe, but we have a little over a mile of 6- and 8-inch. I was rather surprised to hear people say that the pipes were tumbled into the ground. Our practice has always been for all kinds of pipes to lower it down with a rope. One speaker said that, in regard to the cutting of pipe, it was liable to crack. Our experience is that it cuts very much better with wheel cutters. We do not cut it with anything else, except if we have to do it in a confined space. In regard to tapping, we use the Muller tapping machine and have not altered our arrangements at all. We find that the thread is a very much better thread. We get better results from it with the deLavaud pipe than we did with the others.

Wm. W. Brush:[5] Do your tappers make about the same progress in tapping, about the same length of time?

William J. Willson:[7] I have timed both cases and there is practically no difference between the two in tapping.

L. VanGilder:[8] I just want to add my testimony to the value of the deLavaud pipe. Two or three years ago we began getting some shipments, carload shipments of 6- and 12-inch pipe. We had a little difficulty at first; the 12-inch pipe came from Birmingham, as I understand, through the representative of the United States Company. The trouble was in annealing, but since they have been annealed, we have had no difficulty with it at all, and this year's requirements for the entire year's contract has been with deLavaud. It has been eminently satisfactory and answering Mr. Brush's question about the size of the pipe, I would say that we have no difficulty in putting in 2-inch screw taps in 4-inch pipe, which would be the maximum size of tap and the minimum size of pipe for our use.

Robert B. Morse:[2] We have found the wheel cutters unnecessary. We used them at first, but our men now use with perfect facility the ordinary cold cutter.

Mr. Fletcher: I think possibly mention should be made of our particular situation. Most of our trenches are dug through sand, and the last 2 feet possibly are in a clay bottom. We have one man who handles this pipe, throws it into the pit and it is thrown with the bell end over against the soft sand cushion and rebounds so there is no danger of any breakage. We have not had any breakage with the sand cast pipe. The deLavaud pipe requires two men to lower it down with ropes. That means an extra man in our particular situation. Other situations may be different. The same is true in unloading the pipe from the wagon; they roll the sand cast pipe off and drop it down a considerable distance in new allotments where there is more or less soft cushion and grass. We could not do that with the deLavaud pipe, and it requires another extra man. That is why I made mention of the fact that in our particular situation it requires two more men, and that amounts to more than the difference in the cost of the two pipes. With that careful handling, the deLavaud costs us more money. I am also wondering whether any of you have used it long enough to know whether you have expeienced any trouble with this heavy truck traffic, with the rebound from trucks, etc., transmitted to this pipe, that you all admit breaks more easily than the sand cast, or have you used it under railway tracks where even the sand cast pipe breaks? I have not had any experience, because I have not placed it under railroad tracks, but I have been wondering whether anybody has.

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[7] Superintendent, Greenwich Water Company, Greenwich, Conn.

[8] Engineer and Superintendent, Water Department, Atlantic City, N. J.

Robert B. Morse:[2] We have probably made a dozen or more railroad crossings with deLavaud pipe, with no trouble at all, and had no apparent trouble under heavy traffic. Our mains are laid with from 4 to 4½ feet of cover, and there has been no breakage at all except in those places I spoke of, which were all in one or two shipments of the pipe. A cover of 6 feet is used under railroads.

Mr. Sayre (Montreal): I would like to bring up one phase of the question, and that is we buy our pipe by weight, based on the standard specifications for Class C pipe. I was wondering how we could buy a lighter pipe and a denser pipe on those specifications in open tender? We have not used any of the lighter pipe for that very reason; we have successfully defended in court claims for pipe breakages based on the fact that our pipe was the standard weight and thickness, and much as we would like to use lighter pipe, we have not been able to have the weight of the specifications behind us to do so. In our specifications we ask these weights, and we do not see how, if we changed that, and got a lighter pipe, we could avoid getting in trouble as it would not be covered by the standard practice of the specifications.

Stephen H. Taylor:[6] We add to our standard specifications the fact that proposals will also be received for deLavaud centrifugally cast pipe, which takes care of the contract end of it. I should think as far as the legal end of it goes, we have never had any experience along that line, but if we follow the standard and buy pipes that are guaranteed for the pressures we are carrying, I should think we would be on as safe ground as with the sand cast pipe.

A Member: Answering the question of the gentleman from Montreal, our experience is this. Our specification was based fully on Class D, with an invitation for an alternative proposition on deLavaud pipe of equal strength and carrying capacity, and our bids were more favorable from the deLavaud people. As far as railroad claims, perhaps, knowing the standard weight of equivalent pipe in deLavaud, which I am sure the manufacturers would be glad to give, would let us out. For instance, a Class B, 6-inch, weighs 400 pounds and deLavaud weighs wbout 325 pounds for a similar length.

William J. Willson:[7] Prior to my coming to the convention, there was a private development which had used about 9000 feet of 4- and 6-inch deLavaud pipe. This was put in connection with our system. Being a little skeptical about the use of deLavaud pipe, I thought it was a good opportunity to try it out at the expense of some one else. We subjected all that pipe to 310 pounds pressure after it had been laid in the trench. Of the total amount that had been laid, we found nine lengths of pipe that had to be removed, which had probably been fractured in handling either in the shipment or delivery on the job. The reason we did not put any higher test than 310 pounds is because the pressure would not go any higher.

INVESTIGATIONS OF THE NORTHERN END OF LAKE OKEECHOBEE FOR DEVELOPMENT OF POTABLE WATER SUPPLY[1]

By W. E. Darrow[2]

PHYSICAL CHARACTERISTICS OF LAKE AND SURROUNDING TERRITORY

When one enters that section of the state of Florida which lies between the hill region of Lake Stearns and the ridge section of the Eastern Coast, especially if one motors across this territory, using State Road No. 8, one is impressed with the fact that the elevations continue practically uniform for miles, changing only by a few feet, and very gradually. This is especially true if one turns south on Parrott Avenue in the City of Okeechobee, and pursues his way over the greatly improved highway to Lake Okeechobee, the shore of which lies approximately three miles south of the center of the town. The average ground elevation of the city is around 31 or 32, Punta Rassa Datum, and the average stage of the lake for the last two years has been about 17.75 to 18.

For the information of those present, who have not traversed the lake, or who have not been over the Conner's Highway, which opened up this large body of water to the acquaintance of many who had not touched the extensive shores of it, the distance from the north end to the south end of the lake is about 60 miles and the east and west dimension is about 45 miles. The greatest depth, as a matter of record from the recent surveys of Captain Graham of the United States Coast and Geodetic Survey is about 17 feet, when the stage is held at the required government level.

REASONS FOR TURNING TO LAKE OKEECHOBEE FOR WATER SUPPLY

The City of Okeechobee has been for the period of its existence as a city, up until June of this year, under the handicap of using a very hard water, supplied by wells. When equipment was first installed for giving the town a supply from the wells, the water was pumped directly into the elevated tank. In 1924, a device for simple aëration, and a concrete settling basin of 50,000 gallons capacity were constructed as additions to the old plant at the well, under the direction of F. E. Lawrence. Before this time and throughout the period of use of the well water, experience in the use of ordinary galvanized pipe for house connections, and ordinary bath room and plumbing fixtures, demonstrated that maintenance costs both to the city and to private property owners were continuing to mount. The average life of galvanized iron pipe connections was about three years. The deteriorating effects on plumbing fixtures caused leakage to be continual, beginning a short time after installation.

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[1] Presented before the Florida Section meeting, November 18, 1926.

[2] Engineer, Winter Haven, Florida.

As to the quantity of the supply available from the wells, it was found necessary, even before the new plant was well under construction, to drive an additional well, which was comparatively shallow, but gave a good flow equal to twice that of the 800 foot well. However, with this additional amount being pumped to the aëration basin daily, it was necessary to fill and refill the elevated tank so often, that, without constant watchfulness, there was considerable danger of the town going without water. This, by the way, actually did happen several times, due to break down in pumping machinery and other causes which are bound to occur where such a hand to mouth supply exists.

In less than six months after the aëration basin had been put into use, the city authorities decided to have additional investigations made of the water of the lake and, if approved by the electorate, to take the necessary steps to obtain their supply from this source, which was known to be soft.

COMPARISON OF PHYSICAL, CHEMICAL AND BACTERIOLOGICAL CHARACTERISTICS

Chemical analysis of samples of the up town well water gave results showing a total hardness of about 370 p.p.m.; the bacteriological analysis was very satisfactory.

Samples of the lake water secured during the year of 1925 at varying levels, and in quarter square mile areas, extending one mile in all directions from the approximate point of intake, gave average results, in parts per million, as follows, from the chemical analyses as determined in the office of the Chief Engineer of the State Board of Health:

Total solids	210
Alkalinity most of which is of a temporary character	56
Chlorides	38
Color	66

I do not have the record of separation into items of carbonate and sulphate hardness here for reference, but the average total hardness so far recorded is 49 p.p.m. in the lake at the northern end.

Analyses in May, 1926, showed the following results of water from the intake of the new plant.

		RESULTS
Physical:		
Odor	Cold	None
	Hot	Faintly fishy
Turbidity		5 p.p.m.
Color		92 p.p.m.
Chemical:		
Solids	Total	152 p.p.m.
	Loss on ignition	93 p.p.m.
	Fixed residue	59 p.p.m.
Total hardness		49 p.p.m.
Alkalinity		48 p.p.m.
Total chlorides		23 p.p.m.
Free CO_2		2.5 p.p.m.
Total iron		0.25 p.p.m.
pH		8.0

It will be noted that in both reports on average results that the color is high and it is found that color removal is probably the most important function to perfect in the purification plant.

The bacteriological analyses have shown a very high bacterial count, but none of the B. coli type in any of the samples.

The report of R. E. Rose, State Chemist, in 1924, of analyses of samples taken from an unidentified location in the lake, shows the following results:

Total dissolved solids, 297 p.p.m.
Volatile matter, 81 p.p.m.
Qualitative analysis shows chlorides, and sulphates of sodium, calcium, and magnesium.

Reports a soft water, alkaline in reaction.

States that the water is substantially a rain water, the color of which is affected by vegetable humus.

EFFECT OF VEGETATION AND FISHING INDUSTRY

The lake, as well as its tributaries are affected, during a large part of the year, by the water hyacinth, which grows in large masses, completely choking arms of the lake, and when dying off year after year, the humus of these plants, as well as of other vegetation, give the waters the heavy proportion of color reported above. There is little opportunity for the vegetable humus to settle deep enough to stay out of reach of the effects of wave action, and thus it is stirred about sufficiently to remain in suspension. In the deeper rivers, for example, the Kissimmee, approximately the same proportion of color has been noted, but it is pointed out that where greater depth is had, the swiftness of the current keeps the humus and finely divided material from settling to a sludge condition at the bottom.

It might be stated that wind action effects a quick stirring of the waters of the lake throughout, it being a comparatively shallow basin as noted above.

Many forms of fish life abound in the lake in certain years more than at other times. The fishing industry, according to the statistics of Leon Latour who has been in the wholesale end of that business for a long time, has been good in the past, but since 1924 there has been a falling off due to various reasons. As far as the industry itself is concerned, the writer believes it is a good thing for the water supply, providing the fishermen or companies operating always obey the state law in regard to disposition of the material from the skinning benches. This regulation requires that all such material shall be buried at certain depths on shore, and not deposited in the lake. It is believed that sufficient activity of the local law enforcement officers, as well as the water works superintendent for the city, is taking place at the northern end of Lake Okeechobee, to obtain the coöperation of the fishermen, thus preventing any undue contamination of the water in the territory under discussion.

The wet season, with its occasional extremely high stages, has its effect not only on the characteristics of the lake water, but also must be taken into account in the design of the structures of a purification plant, as will be noted below. As yet the writer has had no opportunity to investigate the conditions of extreme low water occurring in some of the dry seasons, and when, from the last eleven years rainfall and lake stage chart, it is noted that extreme low water has reached the elevation of 13.9 we can assume that there has been and is apt to be considerable change in the characteristics of the lake water when considered from the water supply standpoint. The stage of the lake level for the last three years has ranged between 16.9 and 19.0.

Considering the lake as a large impounding reservoir some study is being made of the characteristics of micro-organisms present. There is not, to the knowledge of the writer, any data available, and of course it is necessary, in order that the data be worth something, that investigations along this line extend over a period of years.

THE WATER PURIFICATION PLANT AND PUMPING STATION CITY OF OKEECHOBEE

The problem of securing suitably located property for the erection of a water purification plant and pumping station for the City of Okeechobee was rendered quite difficult, due to the prevailing prices of lake shore real estate. The property purchased by the city is located approximately 1000 feet west of the northern end of Conner's Highway, and includes a portion of the so-called ridge or rim of the lake basin on which the plant proper is located, in order to get all the advantage possible in the construction of the main drain. The average elevation of the top of this ridge is about 23.5 and taking this into consideration, along with the work that undoubtedly will be accomplished by state and federal coöperation in keeping the lake stage at the required government level, it is believed that the wash water and wastes of the plant will always be taken off without trouble, but anticipating possible setbacks, a reinforced concrete apron was constructed at the outfall of the main drain, and doweled sufficiently to receive the necessary side walls for a future sump, in case the waste drainage might at anytime have to be pumped. This arrangement will also prevent flood waters from rising into the low lift pump pit, in case such a thing could happen.

Capacity

The plant will provide a supply of one million gallons per day of twenty-four hours.

Structures

The plant consists of an intake, pumping station, chemical mixing arrangements, coagulation and sedimentation basin, filters, chlorinating plant, filtered water reservoir and high lift pump chambers. All structures are of reinforced concrete, requiring good foundations. Scarcity of suitable filling material prevented the use of paved slopes in constructing water containers, except in the case of the coagulation basin, where considerable hard work was experienced in getting a water tight job.

The intake screens, two in number, are located within a timber pier, approximately ¾ of a mile from the shore, and are connected to the intake valve chamber by a 14 inch diameter cast iron pipe line. Ways and means of reducing the cost of constructing the intake were analyzed, but it is believed that the results of the first hurricane, which occurred in August of this year, demonstrated the use of the long pipe line. As a matter of record the blow carried the waters practically clean, exposing the lake bottom, about 200 feet beyond the intake, although the waters receded within an hour.

The pumping station is built of red tapestry brick, the copings of which are precast reinforced concrete. The structure is designed in a manner to save space; to reduce suction heads to the minimum; to give easy and ready access from pumping station main floor to the filter operating floor, and part of the building walls are made common to the side of the pump wells, and to one side of the concrete walls of the settled water conduit and filtered water conduit, which form a multiduct.

On the main floor, are located two high duty pumps, the incoming panel switch for the 2300 volt circuit; three 7½ k.v.a. transformers for furnishing the 220 volt current to the low duty pumps and for lighting the building and works; the indicator recording pressure gauge for the discharge main; the indicator recorder of the venturimeter of the discharge main; the wash water rate controller, implement and storage room, lavatory, and telephone. In the lower level are placed two intake pumps, with starters, the manifold piping from the intake chamber, and the dry feed machine and suction box for introducing the coagulant into the manifold. The high duty pumps consist of one 750 g.p.m. two stage centrifugal pump, driven by a 75 h.p. ball-bearing motor, and one 350 g.p.m. two stage centrifugal pump, driven by a 40 h.p. ball-bearing motor.

The low lift on the intake is operated by two 1000 g.p.m. single stage centrifugal pumps, each actuated by a 15 h.p. ball bearing motor. Pumps and motors were manufactured and furnished by the Fairbanks-Morse Company.

The coagulation basin is designed with sloping sides and three round-the-end baffles, the top dimension being 90 feet by 100 feet and depth 12 feet, with a capacity of 500,000 gallons. Provision for convenient drainage and cleansing of sludge is made through a double shear gate chamber into which are connected three 12 inch concrete troughs built into the bottom of the basin.

The piping and appurtenances in the pipe gallery are reduced to a minimum, only such material being used that will control the influx of settled water and the passage of the effluent through the rate controllers, pipe being used for the introduction of the wash only. The mains for settled water and filtered water, as well as for the main drain, are conduits of a three story multiduct.

Two filters of a nominal capacity of 500,000 gallons daily, each, have been completed, with such a flexible design and layout, that additional plant capacity can be conveniently added in the future, with a minimum of delay and inconvenience to the present plant. The construction of the underdrains not only affords an excellent distribution of the wash water without cross riffles, but forms a definite economy in filter underdrain design. Essentially the system consists of A-1, 2 inch by 8 inch Y.P. timbers placed on edge at fixed spacing of one inch between slats, the spacers being secured by brass screws. However, a detail of the design includes a properly shaped reinforced concrete bottom or invert of the filter.

The filtered water reservoir has a capacity of 750,000 gallons and connects with the filtered water conduit, through a 24 inch sluice gate. It is connected to the three compartments of the pump well, each connection being a 24 inch sluice gate, and can be drained completely through a 12 inch sluice gate connection to the main drain. It can also be cut off from the plant completely, and the filter effluent turned directly to the pump chambers; affording opportunity for inspection or cleaning.

As much storage capacity as the available money would permit has been provided, for a number of reasons, among which is the fact that the city decided to use current from the local power company, with no stand-by in the pumping station, the line furnishing the current being a single, side circuit on a pole line 2½ miles in length and subjected to heavy wind storms. And again, deeming it wise to provide no cross connection whatever, for bypassing the treatment plant, which fact prevents the use of raw water in the mains, considerable storage was rendered necessary.

All filtered water is sterilized with a Wallace & Tiernan Chlorinator Type M.S.A., the chlorine being applied directly into the filtered water conduit before the effluent reaches the sluice gate outlets.

The cement lined, cast iron force main to the city proper is 2½ miles in length; uptown pressure distribution being effected by a new 250,000 gallons elevated tank now under construction, and by the old 50,000 gallon tank in the northwestern section of the town.

Valves and sluice gates were furnished by the Michigan Valve and Foundry Company of Detroit, R. D. Wood & Co., Philadelphia, and the Columbian Iron Works, Chattanooga.

Rate controllers were furnished by the Simplex Valve & Meter Co., and the venturi meter by the Builders Iron Foundry.

Pipe and special castings were furnished by the American Cast Iron Pipe Company.

Intake pipe was furnished by the Central Foundry Co., N. Y.

The Dry Feed Apparatus was furnished by the F. B. Leopold Co., Inc., Pittsburgh.

The Bowyer Company of Okeechobee was the contractor for construction of the plant and general installation.

R. M. Mitchum & Co. of Augusta, Ga., laid the pipe lines and completed the lake intake.

REPORT OF METROPOLITAN WATER BOARD OF LONDON

TWENTIETH ANNUAL REPORT ON THE RESULTS OF THE CHEMICAL AND BACTERIOLOGICAL EXAMINATION OF THE LONDON WATERS FOR THE TWELVE MONTHS ENDED MARCH 31, 1926,

BY SIR ALEXANDER HOUSTON

An Abstract by Norman J. Howard[1]

The year 1926 marked the twentieth anniversay of Sir Alexander Houston's appointment as Director of Water Examination for the Metropolitan Water Board of London, England, and in his twentieth annual report he has included a historical review of the New River, which supplies a large portion of the Metropolitan area. The history of this supply is vividly portrayed on some 38 pages, and takes us back to the year 1611 about which time the New River scheme was being promoted by Sir Hugh Middleton. The article not only is of great historic interest, but also illustrates the enormous importance of intelligent foresight in providing for a future water supply: the breezy literary style is an additional attraction. The fact is of interest that the price of an original "Adventurers share," amounted to about $1680 in 1610, while in 1898, some 278 years later, part of a share was sold in London for $642,000.

Chlorination of River Thames water. Instead of being stored in the Staines Reservoirs, water is being pre-chlorinated which not only partially purifies it, but also saves the cost of pumping into the reservoirs, estimated at $52,300 for 24,540 million gallons treated. After treatment 48 per cent of samples were negative for B. coli in 100 cc. Average dose of chlorine was 0.4 part per million and cost was 19.6 cents per million imperial gallons.

Chlorination of New River supply. This supply was treated with chlorine for sterilisation and with potassium permanganate and ammonium chloride for taste prevention. Chlorine was applied on 137 days, permanganate on 103, and ammonium chloride on 40 days.

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[1] Bacteriologist in Charge, Filtration Plant Laboratory, Centre Island, Toronto, Can.

Total cost of chemicals per million gallons of water treated amounted to 41 cents. Average dose of chlorine was 0.283 part; of permanganate, 0.205 part; and of ammonium chloride, 0.747 part per million. Taste was reported in the New River supply on two days; in comment on which the author states "The set-back was of the slightest, the matter being remedied almost at once, but its occurrence only shows the necessity of skilled supervision, continuously exercised, and the importance of narrowly watching changes in weather and in the quality of the water being treated." As regards purification effected, results are slightly in favor of the chlorine and ammonia combination.

Leptospiras (*Leptospirae*) *in water.* An entirely new study which seemingly may be of great importance is mentioned for the first time in this report. Section 111 deals with the possibility of spirochaetal jaundice being in part water borne. In 1922 a seaman fell into the Thames and was nearly drowned. He swallowed a lot of impure water and within a few days developed a typical attack of spirochaetal jaundice, and the leptospira which presumably caused the disease was found in guinea-pigs inoculated with the patient's blood. This type of infection has been largely associated with wet conditions, e.g., wet trenches in France, paddy fields in Japan, and wet mines in Scotland. Most authorities, however, consider that the real carriers of the disease are rats. Recent work by Okell and his colleagues would suggest that dogs must also be considered as potential, though probably not important, sources of danger. Details of the recovery of leptospirae from slime in the damp roof of a tunnel following an outbreak of spirochaetal jaundice are given. A culture of leptospirae was recovered from the Deptford Garden Well which is part of the London supply and a water of remarkable purity. In discussing this, Houston states that "it may be said that the result confirms Buchanan's experience that leptospirae, living apparently under saprophytic conditions, may on occasion, possess pathogenic properties, so far as the lower animals are concerned." Later he states "A water might readily be contaminated specifically by a leptospiral rat and so be in a condition to produce the disease (it should, however, be remembered that although saprophytic leptospirae must be often swallowed, they are apparently absent from normal human feces) and, further, such a water might possibly in passing over slimy materials or other suitable pabulum allow of pathogenic leptospirae establishing themselves in the slime and multiplying there. Such a slime would presumably have specific pathogenic properties, and it is impossible to say how long this potentially infective property would persist. The writer is here assuming (on the basis of Buchanan's experience) that pathogenic as well as saprophytic leptospirae can multiply in slime. Although the writer is inclined to think that the rat poisons water and slime, it is possible that Buchanan would reverse the process and say that water and slime may, independently of any mammalian infection, be the means of conveying the disease to rats. Recent experiences seem to point at all events to the desirability of avoiding "dead-ends" in a water system, of taking water for drinking purposes direct from the main, and of having cisterns kept clean, covered, and inaccessible to rat pollutions. Old defective "washers" may not improbably be a nidus for leptospirae, so a dripping tap should, apart from the question of waste, carry a warning of possible danger. At least this would be the view of those who attach importance to the multiplication of these organisms. All will agree on the desirability of an intensive campaign against rats and generally on the avoidance of damp filthy places and impure surroundings.

As regards water supply, the writer is in a quandary; for, as will presently be shown, leptospirae are present in filtered waters as well as in the raw sources of supply, and even deep wells come within the same category. Moreover, since leptospirae can pass through Berkefeld filters, which hold back all the ordinary bacteria, sand filters would seem to be useless in this connection. It is not improbable that not all the leptospirae met with in filtered waters are derived directly from the leptospirae in the raw waters. It is impossible to imagine the complete absence of slimy conditions in connection with a system of water supply (storage reservoirs, filters, underdrains, filter wells, service reservoirs, mains, etc.). It is quite probable that at many points leptospirae may be in course of multiplication and detachment. If water leptospirae are to be feared, it is not perhaps these that are objectionable, but rather those in the impure water antecedent to the purification processes which may have been derived from dangerous sources of contamination. Fortunately, leptospirae are easily killed by means of chlorine, and the dose required is less than is commonly used in connection with chlorination processes. Although the writer does not consider (apart from the puzzling Garden Well result) that the leptospirae in pure and well-purified waters are of much, if any, significance, others may hold contrary views, and to these chlorination must have an irresistible appeal. The subject presents endless fields for future research, is of immense interest, and is agreeably novel, but so far as Londoners are concerned the writer feels that there are no grounds for anxiety.

Search for Leptospirae in water. Hindle's method was used for isolation purposes. Consists of placing 20 cc. of water in sterile petri dish to which is added small amount of human feces and after mixing thoroughly incubate at 25° to 28°C. for about ten to twelve days. A loopful of the mixture is examined under magnification of 1000 diameters and the leptospirae have the appearance of gyrating streptococci. The ends have a hook-like appearance; the movement is axial and stationary rather than progressive in character. Frequently towards the ends a characteristic bulging rotary movement occurs giving a sort of halo-like effect. Morphologically these saprophytic leptospirae are apparently indistinguishable from Leptospira icterohaemorrhagiae, the cause of spirochaetal jaundice, or Weil's disease. If results are negative, specimen should be examined daily up to twenty days. A series of experiments indicated that normal feces do not contain the leptospirae but furnish one of the best mediums for cultivation. A large number of tests were made on the London waters for the presence of leptospirae, which were recovered from several sources including raw water, filtered water and numerous well supplies. With one exception all of the cultures were found to be non-pathogenic. The one positive specimen previously mentioned as occurring in the Deptford Well resulted in the chlorination of the supply. In this case super- and de-chlorination had to be practised on account of the susceptibility of this particular water to taste. There was no evidence of sickness among the consumers of this supply and the chlorination was only undertaken as a precautionary measure. Houston states "There is no evidence, so far as the writer knows, to show that London water consumers are suffering from leptospiral infections of water origin, although millions of leptospirae must be ingested daily. These facts should be borne in mind in judging other supplies. The writer foresees the possibility of cases of Weil's disease occurring, and in searching for the cause. Water is being unjustly blamed, owing to the presence of harmless leptospirae. It is not suggested that water is incapable of carrying infection. Waters contaminated with the discharges of animals suffering from epidemic jaundice would presumably be potentially, if not actually, a serious source of danger. The impression sought to be conveyed is that until we can distinguish between saprophytic and pathogenic leptospirae the greatest caution should be exercised in forming conclusions."

Chemical and bacteriological figures relative to pre-filtration waters are given. Exhaustive figures are included on operation of primary rapid sand filters which were built at Barn Elms, works which have shown that with primary filtration, the slow sand rate can with advantage be increased to approximately three times the normal figure. The average rate of filtration of the primary filters was 140.4 million gallons per acre per day while the percentage of wash water was 3. Sections 6, 7, and 8 deal with *meteorological notes*, *suspended solids in Thames River water,* and *miscellaneous* topics. In the last named section, the subject of iodine, goitre, and water supply is discussed. Reference is made to the Hunterian lecture delivered in London by Sir James Berry on "Some clinical aspects of simple goitre with remarks on its causation" in which he states: "I may refer to an excellent paper on the subject by Dr. James Wheatley, M.O.H., for Shropshire, who gives the preference to the iodization of salt, and to another by Sir A. C. Houston. It is to be regretted that both these writers appear to fully accept the lack of iodine theory. There is at least some evidence that iodine poisoning may occur from the indiscriminate administration of iodine." Houston in replying, discusses the subject and refers to his comment contained in his nineteenth annual report which stated in part: "Although it seems reasonably likely, if not certain, that the wastage is due primarily to a deficiency of iodine in liquid or solid foodstuffs and accessories, it may possibly be true that the gland in some way conserves its store, provided no toxic factor is introduced to upset the equilibrium of its normal working. That the artificial exhibition of iodine has been shown to be a prophylactic measure of value does not necessarily prove that the essential cause of thyrodism is solely due to a deficiency or absence of iodine in the diet. It may only mean that when certain mysterious states of toxicity exist, the only way to prevent the sustained loss of iodine is to counteract the loss by sustained ingestion. Further, we cannot deny that in certain hypersusceptible persons iodine would seem to be actually contraindicated. Nor must it be forgotten that some authorities dispute the iodine theory, and hold that other hypotheses of goitre causation (e.g., fatigue) should be explored before coming to a decision, and others seemingly go even further, and dispute altogether that definitely beneficial results have resulted from the exhibition of iodine." Berry's conclusions as to the causation of goitre are as follows:

1. Simple endemic goitre is not a hypertrophy, but essentially a degeneration of the thyroid gland. The gland is not over-active but under active.
2. Whatever may be the connection between iodine and the thyroid gland there is no reason for believing that a lack of iodine has anything to do with the causation of endemic goitre, as found in the human subject.
3. It is quite certain that, at least in the vast majority of cases, the disease is produced through the agency of drinking water.
4. There is much evidence that practically all waters which produce goitre contain frequently, although not necessarily at all times and seasons, mineral matter in suspension, usually in an extremely fine state of division.
5. There is also a good deal of evidence that this mineral matter is generally of a calcareous nature.
6. Organic matter in suspension, although capable apparently of causing a hyperplasia of the gland, at least in animals, has not proved to be the cause of endemic goitre as seen in man.

Berry's paper is supported with hard facts. In one instance he brings forward the remarkable case of a school in North India where over 80 per cent of the children were affected with goitre until a new, and as it proved an iodine-free, water supply was introduced, when the incidence fell to 2.2 per cent and this apparently without alteration in the food supply.

Sir Alexander Houston in discussing Berry's paper wonders whether the mineral matter in suspension may not be merely an accompanying factor and not the "causa causans" of the disease, or, alternatively, whether the calcareous mineral matter in suspension in water produced by the operations of Nature may not be different in some way from artificially produced precipitates. On the subject in general he has an open mind and states that "If lack of iodine is the cause, should waters containing little or no iodine be medicinally treated, or should the iodine be administered in some other way, e.g., as iodised salt. If turbidity is the root of the trouble there should be no difficulty in removing it by filtration, although in certain cases preliminary coagulation by means of sulphate of alumina is indicated. If, however, potential turbidity has also to be considered as in the case of hard chalky waters, the position is more difficult, calling for softening processes, and if the lime, or lime and soda, process is adopted, the removal of the last traces of lime by filtration, or by redissolving the lime by means of carbonic acid."

The conclusions of Dr. James Wheatley are given in full. He claims that shortage of iodine is the prime factor in the causation of goitre. This shortage is not brought about entirely by a low intake, but is partly due to factors interfering with absorption and utilisation and to other factors increasing the demand. He advocated the addition of iodine to table salt as the most satisfactory method for meeting the deficiency, and deprecated other methods of application.

Other subjects touched upon in section 8 are swimming baths, sterilisation of new mains, decline of typhoid fever, resistance to filtration and microscopical appearance of the pre-filtration waters. A long series of chlorine and ammonia experiments on the treatment and prevention of taste are included.

Ammonia was added for prevention of taste. It is generally concluded that ammonia slows up the immediate effect of sterilisation following the application of ammonia plus chlorine, but has potential sterilising properties provided a sufficient contact period is given. The combination is an effective remedy for the prevention of taste in some sources of supply. Results are tabulated in three columns, A, B, and C. The figures in A refer to treatment with different quantities of dichloramine (mixture of ammonia and chlorine); in B, to treatment with ammonia plus chlorine; and in C, to treatment with chlorine alone. In dealing with the raw River Thames water, the relative advantages and disadvantages of the treatments were as follows:

Advantages	*Disadvantages*
A. Presumably no taste.	More chlorine required than B or C, but unlike B, only traces of ammonia.
B. Presumably no taste. Less chlorine required than in A or C.	Much more ammonia required than in the case of A.
C. No ammonia needed.	Potential taste troubles. More chlorine needed than in the case of B, but less as compared with A.

Ammonia was shown to be an excellent taste preventer in the case of chlorinated waters, but to possess little value as a taste remover. The ammonia was added first (doses usually 0.1 to 0.2 per million) and then the chlorine to the whole volume of water treated. The method of Harold, in which the ammonia and chlorine are added simultaneously to a minor volume of water produces a more intense reaction resulting in the production of a dichloramine compound. The proportions of the two chemicals are 1 of chlorine to 0.1 of ammonia (as N). Ammonia seemed to behave differently in the case of well waters, as compared with river waters. Super- and dechlorination were completely successful in sterilising the water without the production of taste, even after 1 in 1000 millions of carbolic acid had been added to the well water. For several years past, the Director of the London Water Laboratories has yearly introduced entirely new researches into his reports, and the 1926 report will be found to include new and highly scientific facts.

MORE WATER FOR NEW YORK CITY[1]

A REVIEW

By GEORGE L. HALL[2]

A resolution of the Board of Estimate and Apportionment of June 17, 1921, requested that the Board of Water Supply "undertake studies to ascertain the most desirable and best sources for an additional supply of water for the City of New York and the manner in which the supply can best be delivered to the several boroughs of the City, ..." Reports were submitted by the Board of Water Supply under dates of January 23, 1922, December 18, 1923, and December 30, 1924, for additional pipe conduits and another tunnel for conveying water to the boroughs of Brooklyn, Queens and Richmond. The first two reports were approved by the Board of Estimate and Apportionment and the work authorized is practically completed. Action on the report of December 30, 1924, recommending the construction of an additional delivery tunnel is still pending.

Regarding an additional supply of water to meet the future demands of the City, the Board of Water Supply recommends the development of streams east of the Hudson River by the construction of a series of reservoirs extending from the present Croton reservoir almost to Troy, which will increase the safe yield of the City's sources of supply by 434 m.g.d. The aqueduct from these additional sources will pass through the Croton watershed so it will be possible to divert 121 m.g.d. from that area to the higher level of the Kensico reservoir. The estimated cost of the developments recommended is $347,934,000, not including the new delivery tunnel recommended on December 30, 1924, at a cost of $67,249,000. Regardless of the proposed additional water supply this tunnel is vitally essential to the safety and sufficiency of the City's water supply and its construction should be authorized at the earliest possible time.

Consideration was given to the Housatonic and Delaware Rivers as possible sources of supply. The former lies almost entirely within

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[1] Report of Board of Water Supply to the Board of Estimate and Apportionment on New Sources of Water Supply for New York City, October 9, 1926.

[2] Division Engineer, Maryland State Department of Health, Baltimore, Md.

Connecticut. The Delaware, however, is interstate as between New York, New Jersey and Pennsylvania. The commissioners appointed early in 1923, to draw up a compact defining the rights of each state in the Delaware River, successfully concluded their deliberations on January 24, 1925. This compact was adopted by New York and signed by the governor on March 18, 1925. Pennsylvania has not yet approved, while in New Jersey further progress could not be made until the legislature in July, 1926, authorized a new commission for continuing negotiations. It is believed that further conferences will be held, but the outcome cannot be predicted. It is therefore concluded that it is not advisable to wait further for reaching an agreement with the other states involved, since the needs of New York City cannot be delayed too long, as the present supplies will hardly serve until 1935 and the supply recommended cannot be made available in less than ten years.

The recommendations of the Board of Water Supply are based on a report of Thaddeus Merriman, Chief Engineer, and endorsed by J. Waldo Smith, John R. Freeman and Wm. H. Burr, Consulting Engineers.

During the past nine years, Mr. Merriman points out, the water consumption in Greater New York has increased at an average rate of over 31 m.g.d. In 1925 the average consumption was 847 m.g.d. whereas the total safe yield of all sources is 1100 m.g.d. The available margin—253 m.g.d.—will meet the requirements for about eight years. New and additional sources must be made available before 1935. Compared with other large cities in the country the per capita use of water in New York is conservative as the tabulation below shows:

CITY	AVERAGE DAILY PER CAPITA USE—1925	PER CENT OF SERVICES METERED
	gallons	
New York	139	26.0
Chicago	296	11.7
Philadelphia	165	33.0
Detroit	140	99.1
Cleveland	127	100.0
St. Louis	140	7.7
Boston	115	100.0
Baltimore	127	14.0
Los Angeles	119	99.0
Buffalo	208	16.2

The per capita use of water is reasonable, in spite of the relatively small percentage of metered services and when it is considered that no account has been taken of the transients and commuters who daily use city water. Under most favorable conditions ten years will be necessary to build a new supply system and place it in service, so that every effort must be made to obtain the authorization to proceed with the work as early as possible.

Mr. Merriman investigated and studied all possible sources of supply within a distance of 150 miles. The nearest sources available are the east side tributaries of the Hudson River in Dutchess, Columbia and Rensselaer counties. The line of the proposed aqueduct crosses the Croton watershed. The plan includes the diversion into this aqueduct of a portion of these waters by gravity into the higher Kensico reservoir, thus making possible a saving on the cost of pumping Croton water. The capacity of the aqueduct at Kinderhook Creek will be about 150 m.g.d. to be increased immediately above the Kensico reservoir to about 600 m.g.d. Between this reservoir and Hill View reservoir it is proposed to provide an aqueduct with a capacity of 750 m.g.d. "to provide for transporting the maximum draft during periods of peak consumption." Delivery of water from the proposed developments into the City would be through a deep pressure tunnel recommended in December, 1924, which has a diameter of 17½ feet and is 20.2 miles long. This tunnel will deliver, as well as the water of the new and additional sources, a portion of the Catskill water. It will also serve as a second delivery artery whereby Catskill water, constituting five-eighths of the total supply of the City, may be fed into the distribution system. The present delivery tunnel has been in continuous use since 1915. Any interruption in its service will seriously interfere with the City's water supply. The urgency of providing the second tunnel is emphasized.

The plan presented by Mr. Merriman provides for progressive development which will spread the construction costs over a period of 15 years, to be carried out in three stages: (1) The construction of the new delivery tunnel; (2) the aqueducts from Hill View to Kensico reservoir and from Kensico reservoir to the Croton watershed, the reservoir on the East Branch of the Croton River, the aqueduct from the Croton watershed to Silvernails and the reservoirs on the Fishkill and Wappinger and Rocliff Jansen; (3) the aqueducts from Silvernails to Kinderhook Creek and the reservoirs on the Kinderhook, Taghkanic, Stony, Kline and Claverack.

With the completion of this plan the total safe yield of all the available supplies will be 1534 m.g.d., sufficient for the needs of the City until about 1947. The construction program spread over a period of about fifteen years provides for varying annual expenditures of from $2,000,000 the first year, increasing to $50,000,000 the fifth year, then diminishing during the remainder of the construction period.

THE BIOLOGICAL CONTROL OF IMPOUNDING RESERVOIRS[1]

By Carl Wilson[2]

Whether he anticipates it or not, the engineer who constructs an impounding reservoir for domestic supply is confronted with a problem, or rather, an unending variety of problems, in economic biology. The idea that he is dealing only with engineering structures and a chemical called in common language "water," was shattered years ago, but it is only recently that the water works superintendent seriously attacked the living causes of his troubles on the one hand, or encouraged his aquatic friends on the other. Rarely does a water consumer have any conception of the important part which living organisms play in the quality and safety of the water which he uses so freely. He has a vague, and often erroneous, idea that running water purifies itself, and he is aware that disease may be caused by polluted water, but he is not likely to realize that both effects are due to living things. The observing housewife, whose kitchen tap brings her water which has passed through one or more large reservoirs, may have noticed that the water is softer at the end of summer than it was in spring, but she would never guess that this difference is due to the untiring activities of microscopic plants. The water works engineer who is troubled with evil smelling and tasting water, or who is tormented by hordes of insects in his lakes, knows only too well how important is a knowledge of biology.

In our semi-arid climate, where we are compelled to store immense volumes of water for long periods, and where we have the maximum amount of sunshine, with accompanying high water temperatures, biological problems are not only more varied than in the East, but also more intense and trying. Even the stratification of water in a large storage reservoir, due to temperature differences between the top and bottom waters, is more pronounced here, because reservoirs often receive no influx of new water for months at a time. All summer long and far toward winter, the surface layer of water will be enough warmer than the rest to prevent mixing with water lower down unless wind and wave action should be unusually effective. As a result of this condition, bacterial activity on the organic matter present in the water and in the bottom ooze, quickly absorbs all the free dissolved oxygen, and further bacterial activity must necessarily be of an anaerobic type, with the inevitable production of foul smelling decomposition products which are characteristic of stagnant water. Generally hydrogen sulphide is one of these products. We are told that the thermocline, or line of separation between the deeper, colder, stagnant water, and the upper, warmer, layer of aerated water, lies at a depth of 30 to 35 feet, but in most of our Southern California reservoirs it is likely to be much nearer the top, while in at least one lake with which the writer is familiar it is frequently only ten feet below the surface.

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[1] Presented before the California Section meeting, October 28, 1926.

[2] Director of Biological Laboratory, Bureau of Water Works and Supply, Los Angeles, Calif.

Since the production of objectionable odors in this case is wholly the result of living organisms, the solution of the problem must be a biological one. The answer is, furnish enough oxygen to make anaerobic activity impossible, as bacterial by-products produced in the presence of sufficient oxygen are relatively inoffensive. Complete control of this condition has been obtained in the Lower Franklin Reservoir, on the Los Angeles aqueduct system, by introducing the inflowing water through a pipe lying on the bottom of the lake, and extending from the upper end to within a short distance from the outlet tower. About every 100 feet along this pipe 4-inch openings are provided which shoot jets of water upward, and these jets not only bring to the bottom of the lake a supply of water which is saturated with oxygen, but they also keep the entire body of water in a constant state of circulation. Stagnation never occurs in this lake, and water from the bottom is always as sweet as that at the top.

Lower Franklin reservoir is about a mile long, very narrow, and some 70 feet deep at the dam. Because of its shape, this method of providing circulation is especially effective. The same procedure in Stone Canyon reservoir, which reaches a depth of nearly 200 feet at maximum, is successful, but not to the same degree as at Franklin, due to the greater width and the presence of two large arms which cannot be reached by the pipe system as installed.

Plankton growths in reservoirs afford an outstanding example of the need for control measures, and the methods adopted for their repression are familiar to water works men, as they are almost universally practiced upon open reservoirs. Sometimes, however, algae may be useful, and the destruction of such a growth is not always advisable. On the Los Angeles system we have a reservoir covering an area of about 100 acres, with a maximum depth of 45 feet, and inpounding 700,000,000 gallons, which illustrates the point. Three years ago this lake was drawn down to a small pond of about five acres extent, in order to make some changes in the outlet, and the exposed bottom ooze gave off sufficient odor to cause complaints from some of the nearby residents. To satisfy these people the lake bottom was plowed over and fresh, clean earth turned over the ooze, making virtually a new bottom for the reservoir. Following this, the steep sides, which were subject to storm wash, were oiled and rolled with a view to prevent cutting. When the lake was filled there was no vegetation of any kind below the flowline, and the incoming water was all filtered. Black bass, blue perch, and carp stocked the lake, and multiplied rapidly. Here was a clear case of unbalanced biological conditions—all animal life. Naturally enough, plankton growths appeared, and they were held in check by the usual copper treatments, but in spite of our best efforts the water became stagnant and had to be withdrawn from service. Briefly, the oxygen demand of the fish population (necessary to keep down insects) was in excess of the supply derived from the inflowing water and from surface absorption, so that anaerobic bacterial activity spoiled the water. Artificial aeration with compressors was tried, but owing to the area and shape of the lake, it was not a success. Considerable growths of Scenedesmus, one of the green algae, appeared at midsummer, and were allowed to go on unchecked, as the reservoir was out of service, and practically devoid of dissolved oxygen at the surface. Scenedesmus happens to be one of the most benign algae, but, candidly, we feared to use copper, thinking it would make bad matters worse. Contrary to expectation, as the growth increased the quality of the surface water steadily improved, apparently due to release of oxygen by the green algae as a by-product of photo-synthesis. The plants had saved the day. Since then we have been able to utilize several of the algae in this manner with marked improvement in the upper waters. In fact, this simple expedient has enabled us to retain the lake in service all summer, skimming off the top layers, whereas otherwise it would have been necessary to put the reservoir out of service. Naturally, not all algae can be employed in this way, but generally speaking those members of the chlorophyceae which are known not to be producers of foul odors, may be used.

Not infrequently birds assume importance on reservoirs, particularly those which send water directly into service. Swallows nesting around an outlet tower have been known to add colon bacilli to water which was otherwise perfect, thus necessitating a chlorine treatment that would not have been required. Obviously the remedy is to prevent nesting about the outlet works. In Los Angeles we have had several instances where water fowl have carried Peridinium from the brackish sloughs near Wilmington, or perhaps from the open sea, to our distribution reservoirs. This organism is exceedingly interesting and even useful in the ocean, but it is always an unwelcome visitor in reservoirs, because it makes the water rusty red in color, and imparts a most unpleasant odor and taste when the growth finally dies.

Cormorants are also undesirable about a reservoir, first because they may seriously deplete the stock of fish, and second because of their unclean habits. Like swallows, they haunt the outlet towers and sadly deface the structures. It has been found desirable in Los Angeles to drive them off the reservoirs by shooting.

The worst bird offenders, however, are sea gulls and mudhens. In the fall it is a common thing for 10,000 or more gulls to rest on one of our lakes at night, and the amount of guano which they deposit in the water is sufficient to become a matter of real importance. Probably 30 grams per day per bird is a conservative estimate, and when this is multiplied by the immense numbers of birds present it is easy to see how it may affect the quality of the water. Increase in B. coli content is the least serious result, for chlorination may be made to remove these bacteria. The amount of oxygen consumed in the reduction of the fecal matter is great enough seriously to deplete the available reserve, and when this has been done, anaerobic bacterial activity quickly spoils the water. In the Los Angeles reservoir referred to above, we feel confident that the exhaustion of oxygen has been largely due to birds. Moreover, the fertilizing value of the guano stimulates luxuriant growths of algae, for these plants are quite as susceptible to the effects of fertilizers as are the farmers' crops. To be sure, growing algae furnish free oxygen to aid in the reduction of organic pollution, but many types cannot be permitted to grow long enough to accomplish real aid in this way, for they would give rise to their own peculiar bad tastes in the water. Because of the complexity of these actions and reactions, the problem of control is far from simple, but even here some benefit is to be derived by pitting the activities of plants against those of animals. So far, however, we have obtained our best results by shooting at the birds sufficiently to drive them from the lake.

The control of pollution on an impounding reservoir is at once the most important and most difficult of problems in economic biology. It is well to accentuate the fact that what we desire is *economic* control, for the whole solution of the problem hinges upon economy. If natural purification can be depended upon to accomplish the desired results it would be unwise to spend money to do it artificially. Naturally, gross pollution must be removed regardless of cost, but where adequate storage is afforded and draft is made through a distribution reservoir, too much money must not be spent on the impounding system. Under ordinary conditions it is better practice to regard this branch of biological control as belonging to distribution reservoirs, but of course where one reservoir acts in both capacities, as Sweetwater reservoir, it is necessary to treat the lake as a distribution reservoir and eliminate all possible contamination. This policy has been adopted in the case of Sweetwater, and the company has bought up most of the small holdings around the lake, removing the buildings and holding the land fallow. Continuous chlorination of the effluent is relied upon to provide final protection.

There is one more task which biology may be made to shoulder under some conditions. In the case of a water which is high in temporary hardness, that passes through a large impounding reservoir and subsequently through one or more distribution reservoirs protected by the accepted treatment plants, plankton algae may be made to materially reduce the hardness, perhaps to the entire amount of the temporary hardness. It is well known that these plants are able, after all the free carbonic acid has been removed from water, to attack bicarbonates of calcium or magnesium with the release of half-bound CO_2, which they use as food material. The normal carbonates of these bases, which result from such action, are insoluble, and hence removed from the upper layers of water where photosynthesis occurs. At the end of summer such reduction in our Haiwee reservoir has amounted to 30 or more parts per million of total hardness expressed as $CaCO_3$. To make such phenomena of economic value, it would be necessary to foster algal growths all summer, with no draft through the lake, and just before the autumnal overturn, to draw the softer water from the surface into lower reservoirs. Naturally, conditions making possible this use of biological phenomena will not be found often, but still they do exist. Morena reservoir, on the San Diego system, occurs to me as an example, for draft there is made only once a year, and always after the summer plankton growths have had full opportunity to do their work.

Careful study of the biological factors affecting water under storage will undoubtedly show us many new ways of improving water. The amount of work done by living plants and animals is astonishingly great, and means will be found to direct at least part of these activities for the benefit of man. Perhaps one of the most profitable ways in which small funds can be invested is in detailed and intelligent study of fresh water biology in its economic aspects.

CALCIUM AND MAGNESIUM HYDRATES AS COAGULATING AGENTS[1]

By Martin E. Flentje[2]

The fact that the hydrates of calcium and magnesium, under certain conditions, are coagulating agents is not new, and no attempt will be made in this report to establish a new theory of coagulation. However, the application of the coagulating powers of these two chemicals to the purification scheme at Oklahoma City gave results that were thought worthy of publication.

The clarifying powers of Mg hydrate are due to the gelatinous form of this compound, which rather closely resembles the floc formed from alum. Lime, because of the setting free of hydroxyl ions, causes the setting in motion of the negatively charged clay particles, which upon striking one another form larger masses. These in time settle. This finds application in the muddy western and southwestern waters, which though high in alkalinity, are more easily settled with alum and lime than with alum alone. Among the smaller plants in Oklahoma using turbid river waters, it is quite common practice to remove excessive turbidity with lime alone, and apparently this is the only really satisfactory method of obtaining a properly clarified effluent.

The water supply of Oklahoma City is obtained from the North Canadian river. It is impounded in a 5½ billion gallon reservoir, this giving a long period of preliminary sedimentation and providing a means of catching and storing the softest water available. The water is aerated, softened with lime, clarified with iron and alum, settled, carbonated with flue gases, filtered and chlorinated. A daily average of approximately 8 million gallons per day is filtered and treated over the year. The water fortunately contains very little non-carbonate hardness, and requires only lime for softening.

Up until February, 1926, just sufficient lime was added to the water to reduce the total alkalinity to 50 p.p.m., at which point little or no removal of magnesium took place. The use of alum with iron with no removal of magnesium had been found the most economical method of treating the turbid river water which had been used before the present reservoir was put into service. This report deals only with the stored water of the reservoir, and from the time when it was placed in service until the present. The application of the coagulants has always been under laboratory control and has been reported upon. (Spaulding, Chas. H., Laboratory apparatus helps operate filters. Eng. News-Record, 96, No. 16, 644–45, 1926). With the turbid river water, the method that is described below apparently was of no aid in reducing the high coagulant costs. From February on, however, enough lime has been added to give an excess of from 6 to 12 p.p.m., resulting in a precipitation of a part of the magnesium, and a subsequent lowering of the coagulants required. An average of 95 pounds of alum and 294 pounds per million gallons of iron were required in the 8 months prior to February. These quantities were lowered through over-treatment to an average of 39 pounds of alum and 96 pounds of iron per million gallons, from February to the present. (The period of 8 months prior to February is taken for comparison with the latter ones because the reservoir was put into operation at that time and comparable operating conditions prevail over the whole period. This is shown in table 1, figure 1.) The over-treatment of the water required the addition of more lime, but the amount was almost negligible from a cost standpoint, only 67.5 pounds per million gallons being the average required. The extra amount of lime was determined by multiplying the average parts per million reduction in alkalinity for any one month by the average increase in the amount of lime per million gallons required per parts per million reduction in alkalinity. This then was considered part of the coagulant cost together with the lime necessary for the precipitation of the iron. Putting the matter then on a cost basis, the coagulant cost has been lowered from an average of \$6.43 to an average of \$2.86 per million gallons, a saving of \$3.57 per million gallons. This has been plotted and tabulated in table 2 and figure 2. The increase in the parts per million of Mg precipitated is shown in table 3, figure 3, together with the increase in the lime required per parts per million reduction in alkalinity.

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[1] Presented before the Iowa Section meeting, November 4, 1926.

[2] Superintendent of Filtration, Oklahoma City, Okla.

That the results obtained with this water are largely due to the coagulating action of the precipitated $Mg(OH)_2$ was shown in the

TABLE 1

Characteristics of Oklahoma City water

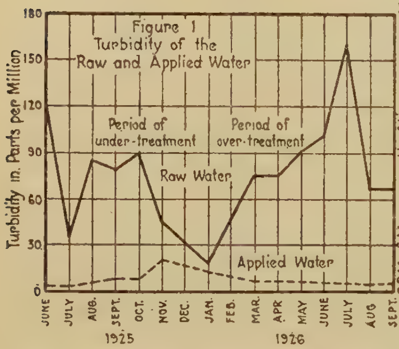
MONTH	TURBIDITY			TOTAL HARDNESS	
	Raw	Applied	Filtered	Raw	Filtered
June	121	4	0.08	276	170
July	35	3	0.05	280	159
August	85	5	0.07	201	123
September	79	8	0.14	211	136
October	88	8	0.09	202	127
November	45	20	0.10	200	125
December	32	17	0.10	195	136
January	18	12	0.08	212	138
February	44	9	0.11	207	117
March	77	6	0.12	229	126
April	77	7	0.10	230	136
May	90	6	0.12	268	154
June	100	6	0.07	249	139
July	160	5	0.11	194	114
August	66	4	0.06	187	102
September	66	5	0.13	192	87

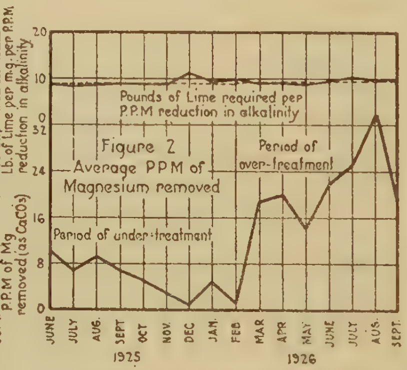
TABLE 2

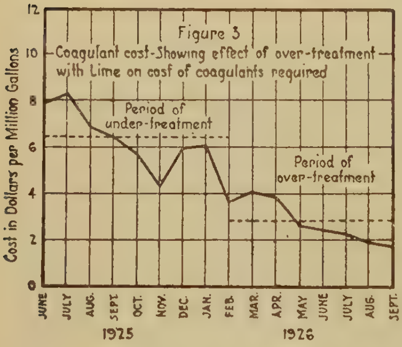
Amount and cost of coagulant

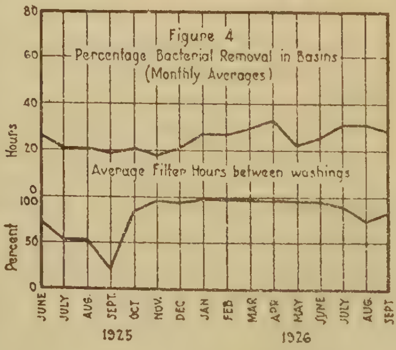
MONTH	POUNDS PER MILLION GALLONS				COST OF COAGULANTS
	Alum	Iron	Lime for iron	Lime for excess	
June	105	369	148	0	$7.81
July	113	388	155	0	8.22
August	92	325	130	0	6.89
September	98	290	116	0	6.43
October	105	239	96	0	5.75
November	49	215	86	0	4.34
December	91	266	106	0	5.92
January	106	261	104	0	6.11
February	61	123	49	64	3.64
March	48	155	62	77	4.02
April	58	131	52	77	3.82
May	29	94	38	84	2.75
June	24	91	36	75	2.55
July	38	69	28	56	2.28
August	27	54	22	55	1.92
September	30	56	22	52	1.89

following manner. A number of composite daily samples of raw water were collected and allowed to settle. The clear water was decanted off, leaving the clay in the bottom of the containers. To this then was added distilled water. This gave a suspension of the same clay as in the natural water, with however only a very small amount of dissolved solids. To portions of this suspension were added various concentrations of lime water, the mixture agitated with a mechanical agitator and allowed to settle. To other portions of the suspension were added equal amounts of a $MgCl_2$ solution, then various concentrations of lime solution. These were then also agitated and allowed to settle. The results are tabulated in table 4, showing that with a precipitation of the Mg, a strong clarifying action takes place. The samples treated with lime alone remain opalescent, very little clarification resulting. This also removes this problem from the hydrogen-ion concentration explanation for optimum results.









Carrying the process still further, it might seem that it would be still cheaper to precipitate more of the magnesium and do the entire clarification in this manner. Some experiments were carried on with this in view and are tabulated in table 5. From this it will be seen that, in order to get a properly clarified effluent, approximately 30 p.p.m. of additional lime would be necessary over that

TABLE 3

Lime used

MONTH	POUNDS PER MILLION GALLONS		POUNDS LIME USED PER PART PER MILLION REDUCTION IN ALKALINITY	PART PER MILLION Mg REMOVED
	Total lime	Lime for reduction in alkalinity		
June	1,180	1,032	8.6	10
July	1,243	1,088	8.1	7
August	948	818	8.6	9
September	934	818	8.9	7
October	837	741	8.8	5
November	936	850	8.9	3
December	1,151	1,045	11.4	1
January	1,055	951	9.5	5
February	1,138	1,089	10.0	2
March	1,219	1,157	9.0	19
April	1,205	1,153	9.0	20
May	1,258	1,220	8.7	14
June	1,240	1,204	9.6	22
July	978	950	10.2	25
August	925	903	9.8	34
September	872	850	9.9	18

TABLE 4

Effect of $MgCl_2$ on clarification

SAMPLE	LIME ADDED	$MgCl_2$ ADDED	CLARIFICATION AND FLOC
	p.p.m.	*p.p.m.*	
1	20	0	Poor floc; slight
2	30	0	Poor floc; slight
3	40	0	Poor floc; slight
4	50	0	Small floc; slight
5	40	40	Good floc; immediate
6	50	40	Good floc; immediate
7	60	40	Good floc; immediate

required to give a slight excess of lime. This amount of lime at 86 cents per 100 pounds would cost slightly over $2.00, or little more than the coagulant cost using lime, iron, and alum, during either August or September of this year. Apparently the maximum benefit is to be derived from the removal of between 15 and 20 p.p.m.

TABLE 5

Effect of lime on clarification

SAMPLE	LIME	ALKALINITY			MAGNESIUM REMAINING	TURBIDITY	
		T.	P.	C.		Forty-five minutes settling	Two hours settling
	p.p.m						
1	105	52	21		48	60	60
2	115	54	27	0	39	34	32
3	125	54	30	6	42	26	24
4	135	55	36	17	42	13	12
5	150	57	44	31	35	2	2

Alkalinity, of raw water	120
Turbidity, of raw water	75
Magnesium, as $CaCO_3$, p.p.m.	58

TABLE 6

MONTH	BACTERIAL COUNT ON RAW WATER AT 37.5°C.	BACTERIAL COUNT APPLIED WATER	PER CENT REMOVAL	B. COLI IN APPLIED WATER, PER CENT SAMPLES
June	2,420	643	73.4	30.0
July	900	425	52.8	10.0
August	1,640	816	50.1	65.6
September	1,275	940	26.4	51.7
October	1,108	183	83.5	64.5
November	476	23	95.2	36.7
December	335	17	94.9	9.7
January	195	6	96.9	22.6
February	222	9	96.0	21.4
March	320	10	96.5	22.6
April	435	21	95.2	17.2
May	851	42	95.3	25.8
June	932	103	89.0	19.4
July	1,540	177	88.5	35.6
August	700	186	73.4	33.0
September	1,110	195	82.5	83.0

of magnesium. The figures above also neglect, in our case, the additional cost of pumping more CO_2 for the carbonation of the added lime.

Another advantage in this method of treatment is the added sterilization effect of the free lime. The variation in bacterial removal due to the shorter detention periods during the summer peak loads has been largely done away with. Table 6 and figure 4 show that a consistent bacterial removal of approximately 95 per cent is obtained in the basis at all times. The decrease in the number of positive B. coli tests has not been all that has been hoped for. This is explained by the fact that the free lime concentration has been too low to give a complete sterilization in the detention period available. It has not seemed desirable to seek complete sterilization in the settling basins as the free lime required to do this would throw an additional load on the carbonating equipment, which is slightly inadequate even now. However with the advent of winter, at which time taste troubles due to excess chlorine are more noticeable, it may become desirable to get a more complete sterilization in the basins. This water during cold weather gives noticeable tastes with free chlorine, at concentrations below which sterilization can be relied upon. However, decided attenuation at least, of any pathogenic bacteria must take place under these conditions. Hoover, Houston and others have shown that bacteria of the colon and typhoid group are killed in from five to twenty-four hours when present in water containing $\frac{1}{2}$ to 1 grain of excess lime. The period of detention in the Oklahoma City basins is from eight to ten hours. Some of the results mentioned above are masked somewhat by the results of a few periods of pre-chlorination of the raw water. This has been done at times in an effort at taste control.

Little change in the length of the filter runs has resulted (fig. 4). These results are not exact as at times it was advisable to wash filters every twenty-four hours regardless of the loss of head. At least no reduction in the length of the filter runs has resulted. In the last few months the filters seemed to be losing some of their ability to remove bacteria. This, however, has not been determined as yet.

Algae growth on the basin walls has been greatly inhibited. An interesting phase of this been the noticeable lack of green growth on the walls of the entire basin, except in the carbonating chambers. Here rather abundant growth of the algae has taken place during the entire summer, due to the removal of the free lime by the CO_2 gas.

SUMMARY

1. The addition of a small amount of lime to the Oklahoma City water over that needed for softening has resulted in considerable saving in coagulant cost.

2. Magnesium hydrate, under certain conditions at least, is an efficient coagulating agent, lowering considerably the treatment cost in a water in which it can be utilized.

3. The presence of free lime in the treated water makes possible—

a. An attractive method of taste control during cold weather, in that less chlorine is necessary.

b. The production of a softer water because of the smaller amount of carbonate hardness introduced during clarification.

c. The inhibition of algae growth on basin walls.

Acknowledgement is made to C. E. Bretz, Superintendent of Water Department, Oklahoma City, for his co-operation in obtaining and for his permission to present the above data.

CITY WATER SUPPLIES IN ARKANSAS

By Harrison Hale[1]

Examination has been made of 92 samples of water from 80 cities and towns of Arkansas. These city supplies varied widely in total dissolved solids. Hot Springs and Mena have only 40 parts per million each, while in three towns of the state the total dissolved solids exceed 1000 p.p.m. This is the limit set for drinking water in standards adopted by the United States Treasury Department, June 20, 1925, as recommended by the Advisory Committee on Official Water Standards.[2] Eighteen towns have less than 100 p.p.m., the average being 268.

Water is generally clear and free from odor and any considerable amount of color. Only eight towns show a turbidity as high as 10 p.p.m. as prescribed in the standards; four others have 5 p.p.m. of turbidity.

No samples approach the 250 p.p.m. limit set for sulfate, the highest being 134. Only two others are as much as 100, the average for all samples being 20.2 p.p.m.

Magnesium, likewise, is uniformly low, only 3 samples being as much as 20 p.p.m., the highest being 31. The limit for magnesium is placed at 100, while the average was 5.4 p.p.m.

In chloride content there is great variation, running from 1.8 to 576.5 p.p.m. Five supplies exceed the limit of 250. Although the average is 44 p.p.m., there are 40 towns with less than 10, the average being greatly raised by a few high results.

Oxides of iron and aluminum were determined together. It is interesting that bauxite, located near the source of more than 90 per cent of the total aluminum ore produced in the United States,[3] showed the highest, 20.5 p.p.m., the next being 11.8. Only 2 others exceeded 7, the average being 3.2 p.p.m.

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[1] Head of Chemistry Department, University of Arkansas, Fayetteville, Ark.; Consulting Chemist, Water Department, Fort Smith, Ark.

[2] Reprint No. 1029 from the Public Health Reports, April 10, 1925 (pp. 693–721).

[3] United States Geological Survey Report, 1924.

For silica, 3 samples exceeded 40 p.p.m., the average being 19.7 p.p.m.

The amount of scale varied widely, being less than 0.2 pound per 1000 gallons at Mena and at Marked Tree and more than 3 pounds in two other places, the average being 1.03 pounds. Pounds of hard scale per 1000 gallons show less variation, averaging 0.367 pound.

Scale and hard scale were calculated in accordance with the formulas given by Herman Stabler's Industrial Application of Water Analyses in United States Geological Survey Water Supply Paper 274 (1911) pp. 175–177. Other determinations were in accordance with the Standard Methods of the American Public Health Association (1923).

There is a general relationship between the mineral content and the geographical distribution. At times, however, waters from sources not far apart show striking differences. This is due to the fact that one may be a surface water and the other from a well.

So far as the sources are known they are in this order: (1) wells, (2) springs, (3) rivers or creeks, (4) lakes. Fifty-eight per cent of those reported are from wells.

In the larger cities and towns filtration and a germicide are generally used, usually chlorination. In some chlorination only is used while in a majority treatment is not yet given.

These results together with data on pumpage and purification equipment are to be published as a bulletin of the Engineering Experiment Station, University of Arkansas. This will contain also the results of bacteriological tests made by the Laboratory of the State Board of Health.

SOCIETY AFFAIRS

CALIFORNIA SECTION

The convention, held at San Diego, October 28, 29 and 30, 1926, was particularly fortunate in encountering bright, warm, balmy Southern California weather which did much to enhance the pleasure and enjoyment of those attending and especially the ladies who were entertained by various excursions while the men were in the convention sessions.

The attendance greatly exceeded the fondest hopes of the committees in charge, and the San Diego Hotel, designated as convention headquarters, could only shelter a part of the members and visitors, so many were quartered at the U. S. Grand and other hotels.

The business dinner held on Thursday evening in the Pompeiian Room of the San Diego Hotel was attended by 240 delegates. The dinner dance held Friday evening by the manufacturers had a total attendance of 383 members, guests and ladies.

The convention meetings were held in the American Legion Hall in Balboa Park, a permanent building preserved from the San Diego Fair of 1915. A large, well lighted hall furnished ample room to house the exhibits of fifty manufacturers, which were exceedingly well arranged and complete and proved a most instructive and valuable adjunct to the convention. The convention meetings were held in the east end of the hall which, suitably screened by curtains made an ideal comfortable assembly room with good acoustic properties.

Invitations had been extended to all members of adjoining states, and in response, there were in attendance, members from Canada, Oregon, Idaho, Utah, Colorado and Arizona. The total registration was 383, classified as follows: Active members—86; Associate members—106; Waterworks men guests—101; and ladies—90.

The program was carried out in accordance with the program below with President C. B. Jackson presiding. The papers were well prepared, but unfortunately were too lengthy to allow time for proper consideration and discussion.

The election of officers to serve for the ensuing year were as follows: Chairman, S. B. Morris; Vice-Chairman, J. J. Ryland; Secretary-Treasurer, Paul E. Magerstadt; Executive Committee, P. Dieterich and J. Burt.

San Jose was unanimously chosen as the meeting place for the convention of 1927, with the San Jose Water Company acting as host.

An address by William Mulholland, Chief Engineer of the Los Angeles Water Department, was easily the banner feature of the convention. The subject of his address was the rapidly growing needs of the City of Los Angeles and the proposed $200,000,000 development of the Colorado River to bring water 231 miles for the City's relief.

On Friday evening the manufacturers were host at a dinner dance at which 383 members and guests were in attendance. After dinner the famous Orpheus Quartette of Los Angeles entertained with several selections. A clever cowboy monologist also favored with several pleasing offerings. An enjoyable dance followed until the early hours of the morning.

On Saturday morning an interesting trip over a portion of the San Diego water system was made as guests of the City of San Diego. A lunch was served at the Lower Otay Filter Plant. The trip was well arranged, both interesting and instructive, and proved a fitting finale to a successful convention.

THURSDAY, OCTOBER 28, 1926

Forenoon

General Get-together Registration and Review of Exhibits.

Afternoon

Address of Welcome. By Hon. John L. Bacon, Mayor of San Diego.

1. Description of the Impounding Works of the San Diego Water System. By R. C. Wueste.
2. The Biological Control of Impounding Reservoirs. By Dr. Carl Wilson.
3. Report on Water Meter Maintenance Methods. By J. H. Fagg.
4. Five-minute papers and discussions.

Evening

Informal Dinner, Pompeiian Room, The San Diego Hotel.
Business Meeting.
Report of Retiring Officers.

Report of Committees.
Election of New Officers.
Selection of next place of meeting.
The Colorado River Project. By William Mulholland.
Moving Picture—From Mine to Consumer. By courtesy of American Brass Company.

FRIDAY, OCTOBER 29, 1926

Forenoon

1. Progress in Electrolytic Chlorination at Sacramento Filtration Plant. By Harry N. Jenks.
   Paper to be read by Ralph Stevenson.
   Discussion by Charles Lundelius.
2. Corrosion Problems of a Water Supply System and Methods of Protection. By E. B. Stewart.
3. Equitable Charges for Automatic Sprinkler Connections. By William Cartwright.

Afternoon

1. Underground Waters and Pumping Therefrom. By George W. Trauger.
2. Water Consumption for Various Purposes in Terms of Depth and Area. By Charles Lee.
3. Iodine in Drinking Water. By George E. Ebright and C. G. Gillespie.

Evening

Dinner Dance—Informal, in the Pompeiian Room, The San Diego Hotel, as guests of the Exhibitors. Selections by "Orpheus Four."

P. E. MAGERSTADT,
Secretary.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, **12:** 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

The Future Development of the Metropolitan Area Surrounding San Francisco Bay.—Charles H. Lee. Bulletin of the Seismological Society of America, **16:** 2, 81, June, 1926. The purpose of this paper is to picture the essential facts and problems relating to the present and future metropolitan area of San Francisco Bay, and to outline what might be done to reduce future hazards to life and property from earthquake and earthquake fires. The included land capable of intensive development covers 876,300 acres, with an ultimate population of between 5 and 6 million, the true value of all taxable property at least $12,000,000,000, of which 50 per cent will be more or less destructible. Future demand for water will be at least 1075 million gallons daily, requiring, in addition to 250 m.g. from local sources the equivalent to full development proposed for Hetch Hetchy, Mokelumne, and Eel River projects. Sacramento-San Joaquin River at head of Bay may also be drawn upon. Reduction of hazard from fire and earthquake may be attained by guiding development on the basis of definite community and regional plans. Following items suggested: Systematic establishment of open spaces in form of broad thoroughfares, highways, parks, etc., to act as firebreaks and places of refuge; preservation of adequate and efficient ferry system in conjunction with trans-Bay bridge or tubes when built; adoption of building codes designed to promote earthquake-proof construction and use of fire resistant materials; adoption of definite program to be followed by electric and gas utilities at the occurrence of an earthquake; increasing amount of local storage capacity in water distribution systems of different communities; utilizing all feasible reservoir sites in Bay region for reserve storage, and, as far as possible, interconnecting all reservoirs and distribution systems, with ultimate aim of completely circling the Bay with transmission pipe line or conduit capable of drawing water from any major reservoirs in case of emergency; establishment of plan of organization, local and general, for handling water problems of future metropolitan area. The interconnection of water systems, although limited somewhat by relative elevations of reservoirs, is quite feasible, and, in the event of an earthquake at any point in the Bay region, might be of inestimable value. Earthquakes have independent origin on either side of the Bay, and major shocks have never been known to occur simultaneously at different points in the Bay region. The probabilities are that damage to a water system serving one unit of the Bay region would not occur at a time when systems serving other units were out of commission. Each independent water system in the Bay region as it is built and extended will utilize the feasible reservoir sites within its immediate area. By interconnection, the supply held by such reservoirs may be made more or less available to other systems. By careful study certain sites might be made available for holding reserve supplies which could be fed into an interconnected series of distribution systems at times of emergency.—*A. W. Blohm.*

Strengthening and Indurating Concrete with Sulfur. W. H. Kobbé. Eng. News-Rec., 96: 940–2, 1926. The strength of concrete can be considerably increased by impregnating with sulfur. The treatment process consists of immersing the concrete in a bath of S maintained at 130 to 150°C., for several hours. Standard tensile briquets of cement mortar which ordinarily break at 150 pounds are increased in strength to over 1000 pounds and as high as 2000 pounds per square inch by this treatment, and strength under compression is similarly increased. Water absorption is usually reduced to less than 2 to 3 per cent.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Underwater Piledriving and Cofferdam Sealing. John C. Pritchard. Eng. News-Rec., 96: 930–3, June 10, 1926. Illustrated description of driving precast reinforced concrete piles for St. Louis intake structure at Howard Bend, and of sealing cofferdam with concrete. Piles, which were cast on job, were 48 feet long and 16½ inches in diameter and were driven to rock inside cofferdam, 538 being used in all. Bottom of cofferdam was then sealed with layer of concrete 5 feet thick poured under water by means of tremie. Total of 3050 cubic yards of concrete were poured in 5 days' continuous operation. After dewatering, reinforced concrete bottom 5 feet thick was poured on top of concrete seal. For high-service pit, 68-foot piles were employed.—*R. E. Thompson.*

Earth Dam Fails by Shrinkage. Eng. News-Rec., 96: 942, June 10, 1926. Brief illustrated description of failure of small earth dam of Loch Alpine Development Company, Delhi, Mich. Construction of dam extended into winter of 1925–1926 and shrinkage had only begun when sharp freezing weather set in. Top and side of embankment froze, forming shell over soft clay below, which continued to shrink and settle, leaving porous condition under frozen shell which resulted in failure during flood following thaw. Recommended that upstream face be lined with stone after damage has been repaired.—*R. E. Thompson.*

Water Works Type Condensers. Wynkoop Kiersted, Jr. Eng. News-Rec., 96: 952–3, June 10, 1926. Advantages of water works type condensers are simplicity of operation and absence of pump auxiliaries attending use of standard type. Without correct design of structural details advantages may be offset by high frictional resistance to passage of water. Two instances of this are cited.—*R. E. Thompson.*

Laying Intake Through Earth Dike Under Service. Eng. News-Rec., 96: 1010–4, June 24, 1926. Illustrated description of installation of 90-inch reinforced-concrete intake at Denver, Colo., which will deliver water from Marston Lake, a 6000-m.g. reservoir, to new 70-m.g.d. mechanical filtration plant. Lake, which has average diameter of 1 mile, has an earth embankment extending around most of perimeter. Intake was laid through 40-foot dike and into lake a distance of about ¼ mile to avoid algae growths, terminating in conical screen on upturned elbow. Cofferdams constructed through dike for pipe and on shore for traveling-screen house, are described and illustrated. As pipe line must act as siphon when lake level is low, airtightness was necessity. This was effected by molding welded steel cylinders into concrete during manufacture of pipe and calking joints with lead. Subaqueous pipes beyond siphon section were only bolted together.—*R. E. Thompson.*

Home-Made Lift Replaces Sidings in Tunnel Construction. Eng. News-Rec., 96: 954, June 10, 1926. Brief illustrated description of air lift being used by San Joaquin Light and Power Corporation in driving tunnels of Balch hydro-electric project in California instead of switch and siding for setting out empty muck cars awaiting return at heading.—*R. E. Thompson.*

Handling a Large Water Flow in the Moffat Tunnel. C. A. Betts. Eng. News-Rec., 96: 985, June 17, 1926. Measures adopted during construction of Moffat tunnel when 3000-gallon per minute water course was cut by main heading described briefly.—*R. E. Thompson.*

El Paso, Tex. Eng. News-Rec., 96: 980–1, June 17, 1926. New 2-to 3-m.g. circular reinforced-concrete reservoir will increase reservoir storage capacity to 25.5 m.g. Water is pumped by motor-driven centrifugals from 6 wells averaging 1.6 m.g.d. each. Additional wells pumped by air increase total supply to 16 m.g.d., which may be further augmented by 2.5 m.g.d. from surface well used only in fire emergency. Centrifugal pumps cost 1.5 cents per 1000 gallons to operate.—*R. E. Thompson.*

A Problem in Plant Layout in Saturated Sand. Eng. News-Rec., 96: 1016–7, June 24, 1926. Illustrated description of laying of foundation of new Jamaica sewage treatment plant, New York City, in wet sand, which was effected by means of circular caisson 82 feet in diameter and 63 feet deep.—*R. E. Thompson.*

Reduction of Mud Balls in Rapid Sand Filters. August V. Graf. Eng. News-Rec., 96: 1031–2, June 24, 1926. Brief description of method employed at Chain of Rocks filtration plant, St. Louis, Mo., for disintegrating mud balls, which consists of jetting sand from one end of filter to opposite end with hydraulic ejector while wash water is being applied. Wash water used during 5-hour period employed for jetting sand in each filter is about 1430 gallons per square foot of filter area. Cleaning filters by this method once every 6 months has reduced mud balls very considerably and also removed part of coating of sand grains due to softening.—*R. E. Thompson.*

Formulas for Calculating the Total Hardness of Water (from Conductivity). B. Markus. Vers. Meded. Betrefende de Volksgezondheid, July 1926, 715–23. Usual formula for calculating hardness in German degrees, D, from conductivity is:

$$D = \frac{K_{18} \times 10^6 - 3\,Cl}{30}$$

where Cl = mgm. per liter of chlorine as chloride. Fleischer's improved formula is:

$$D = \frac{L - 3\,Cl - 20\,K(F_s - F_k)}{F_s}$$

where $L = K_{18} \times 10^6$; Cl as before; K = temporary hardness; and F_s and F_k are average conductivities for 1 degree sulfate hardness and 1 degree temporary hardness respectively. Samples in which L is greater than 850 are diluted with distilled water until L is less than 200, in which case (group V below) $Ld = K_{18} \times 10^6$ for distilled water used in dilution, v = degree of dilution and l = value assumed by L in diluted sample. The following table shows values of F_s and F_k for various values of L.

	$L = K_{18} \times 10^6$	F_k	F_s	HARDNESS
I	1–300	29	40	$\frac{L - 3\,Cl - 20 + 11\,K}{40}$
II	300–400	26	38	$\frac{L - 3\,Cl - 20 + 12\,K}{38}$
III	400–600	24	37	$\frac{L - 3\,Cl - 20 + 13\,K}{37}$
IV	600–850	22	36	$\frac{L - 3\,Cl - 20 + 14\,K}{36}$
V	850 or over (diluted)	29	40	$\frac{vl - 3\,Cl - 20 - vLd + 11\,K}{40}$

Ninety-four Dutch waters were tested and greatest differences between analyses and formulas were +1.2° to −4.2° for ordinary and +1.6° to −2.3° for Fleischer's. Average was −0.69° for former and −0.37° for latter.—*R. E. Thompson.*

Cement Specifications Changed by Missouri Highway Commission. F. V. Reagel. Eng. News-Rec., 96: 657, 1926. To meet conditions in Missouri, two changes were made in cement specifications for 1926, namely, (1) a minimum tensile strength of 225 pounds at 7 days was specified, and (2) a provision was added to the effect that fluctuations in setting time causing finishing difficulties in field would be held cause for rejection.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

New Water Pumping and Filtration Plant, Hannibal, Mo. M. P. HATCHER. Eng. News-Rec., **96**: 727–8, 1926. Additions to the water works of Hannibal, consisting of an 11-million gallon per day electrically-driven pumping station and a 6-million gallon per day mechanical filtration plant, are described. The supply, which is drawn from the Mississippi River, was formerly only coagulated, settled and chlorinated. Modification of settling basin provides storage capacity of 8 million gallons each for raw and filtered water. Lime and alum will only be applied during approximately 2 months of the year, when the turbidity is high. The average water consumption is 2.25 million gallons per day by a population of approximately 19,300.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Methods for the Determination of Oxygen Dissolved in Water in Presence of Nitrous Acid. G. ALSTERBERG. Biochem. Z., **159**: 36–47, 1925. From Chem. Abst., **20**: 790, March 10, 1926. Hydrazoic acid is used to eliminate disturbing effect of nitrite in determination of dissolved oxygen. ($N_2O_3 + 2HN_3 = 2N_2O + 2N_2 + H_2O$.) Solutions containing alkali or mineral acid must be used to prevent the reaction $2NaN_3 + 2I = 2NaI + 3N_2$ from taking place. Remainder of determination is same as that of Winkler. In presence of small quantities of nitrite, hydrazoic acid may be added after precipitated manganese dioxide is dissolved in sulfuric acid. Reagent has following composition: 3 g. sodium hydroxide, 20 potassium iodide and 0.5 g. sodium azide in 100 cc. of solution. Amount used is 1 cc.—*R. E. Thompson.*

Determination of Oxygen Dissolved in Water in Presence of Nitrite. M. E. STAS. Chem. Weekblad, **22**: 584–5, 1925; cf. C. A., 7: 4026. From Chem. Abst., **20**: 790, March 10, 1926. Alsterberg's method (cf. preceding abstract) gives accurate results provided the water is treated with NaN_3 before liberation of iodine. The nitrite content of sewage waters does not exceed 8 mgm. per liter, so 10 mgm. NaN_3 is sufficient.—*R. E. Thompson.*

Rapid Testing Methods for Rust-Preventive Paints. H. WOLFF. Farbe und Lack, 1925, 576–7; Farben-Ztg., **31**: 579–80, 1925. From Chem. Abst., **20**: 831, March 10, 1926. Accelerated tests do not yet with certainty determine most essential properties, durability and rust prevention, of metal-protective paints. Review of accelerated tests is given, with discussion.—*R. E. Thompson.*

Recreational Use of San Diego's Water-Supply Reservoirs. R. C. WUESTE. Eng. News-Rec., **97**: 386–8, 1926. The recreational use of reservoirs in San Diego, which includes fishing and waterfowl hunting, is described. The supply is obtained from water courses which are dry except during the rainy season, the policy being to provide storage reservoir capacity of 2 to 6000 million gallons per 1 million gallons per day safe net yield, the cost of these projects being $500,000 to $1,000,000 per million gallons per day safe net yield. During 1925, receipts from recreational use were $24,440, 75 per cent of which was net profit. The supply is filtered through pressure filters and chlorinated at rate of 2.5 pounds per million gallons. The B. coli index of the treated water during 1925 was zero.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Report, Corporation of Madras Water Analysis Laboratory, 1924–5. S. V. Ganapati. 31 pp. Tabulations of analytical results are given and discussed. The slow sand filters give erratic results and a system of sedimentation, rapid filtration and, when necessary, chlorination, has been recommended. When the raw water is clear considerable time is required for formation of filtering film on filters and as a result the bacteriological results are poor. Under these conditions the formation of an artificial film by addition of alum during the first day of the filter run and subsequently at 7 to 10-day intervals, as required, has resulted in improved efficiency. Difficulties have been experienced with white filamentous growths in the filter chambers, filtered water conduits and reservoirs, which give rise to odor of hydrogen sulfide, particularly on decay. Chlorination and treatment with potassium permanganate have failed to remedy the condition, which is most acute during periods of high temperature. The organism causing the trouble has not been identified.—*R. E. Thompson.*

American Society for Testing Materials, Tentative Standards, 1925.— Separate, 876 pp. (1925); cf. C. A., **19**: 3331. From Chem. Abst., **20**: 954, March 20, 1926.—*R. E. Thompson.*

Reconstruction of the Albany Water Filters. Allen Hazen. Eng. News-Rec., **97**: 380–6, 1926. Recent additions and repairs to Albany filtration plant are described and illustrated in detail. The essential additions were a new coagulation basin and new aërators. The water, which is drawn from the polluted Hudson River, is aërated at inlet to coagulation basin after addition of coagulant, passed through pre-filters at rate of 75–115 million gallons per acre per day, aërated again, passed through slow sand filters at rate of 6 million gallons per acre per day, and finally chlorinated. During 1925 the average color was reduced from 55 to 8. The average number of bacteria in the raw water was 67,500 per cubic centimeter, and in the coagulation basin, pre-filter and final filter effluents, 4,950, 300 and 5 respectively.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Pulling 1200 Feet of 18-inch Cast-Iron Pipe Across Burrard Inlet, Vancouver, B. C. C. Brakenridge. Eng. News-Rec., **97**: 366–9, September 2, 1926. Contract Record, **40**: 811–4, August 25, 1926. Illustrated description of installation of first of four 18-inch flexible-joint cast-iron submerged mains across Burrard Inlet at the Second Narrows, Vancouver, being a section of third conduit extending from intake on Seymour Creek to Little Mountain reservoir near center of Greater Vancouver Water District. Main conduit is 13 miles in length and 36 inches in diameter, constructed of $\frac{5}{16}$ to $\frac{9}{16}$-inch steel. Crossing consists of 1200 feet of completely submerged course and 1200 feet of tidal flat. Pipe for crossing was assembled on chute and pulled or pushed across by cables and pulleys operated by donkey engines. Pipe was actually in motion a little over 1 hour, spread over period of 4 days.—*R. E. Thompson.*

Adjustable Leg on Trestle Aids Pipe Lowering on Side Hill. Eng. News-Rec., 97: 374, September 2, 1926. During laying of 26-inch steel pipe line of Marin Municipal Water District in California, it was necessary to support pipe above trench during welding and then lower considerable lengths into trench. Trestle with adjustable leg developed to facilitate the work is described.—*R. E. Thompson.*

The Chemical and Physical Mechanism of Rusting and Corrosion. O. BAUER. Gas- u. Wasserfach, 68: 683–7, 704–7, 715–9, 1925. From Chem. Abst., 20: 355, February 10, 1926. General review and discussion.—*R. E. Thompson.*

The Present Status of Chlorine Gas Therapy. E. B. VEDDER. Ann. Clin. Med., 4: 21–9, 1925. From Chem. Abst., 20: 451, February 10, 1926. Optimum concentration is 0.015 mg. per liter. Best length of exposure is 1 hour.—*R. E. Thompson.*

Chemical and Physical Studies on Mineral, Particularly Iron, Metabolism. OSKAR BAUDISCH and L. A. WELO. Naturwissenschaften, 13: 749–55, 1925. From Chem. Abst., 20: 438, February 10, 1926. Clear mineral water from Franzensbad, Czechoslovakia (0.0178 gr. ferrous iron per kilogram) was sealed in evacuated flasks. On exposure to light the water became opalescent and turbid, whereas in the dark it remained unchanged. Precipitate formation runs parallel with disappearance of catalytic power of the mineral water; light accelerates the aging. The iron at first is present in the "active" form, described by Baudisch in previous papers. Biological properties of mineral waters are discussed from point of view of Werner's coördination theory and the action of light.—*R. E. Thompson.*

The Salinity of Artesian Waters of Lower and Middle Belgium. (Second Note). J. DELECOURT. Ann. soc. geol. Belgique, 48: B41-B52, 1925. Cf. C. A., 19: 231. From Chem. Abst., 20: 465, February 10, 1926. Description of chemical properties of main flows of Belgium and France.—*R. E. Thompson.*

Supply of Bathing and Drinking Water on Plantation. A. W. A. JACOMETTI. Arch. Suikerind., 33: 1010–7, 1925. From Chem. Abst., 20: 465, February 10, 1926. Description of Jewell installation in Java.—*R. E Thompson.*

Studies of the Horizontal and Vertical Regions of Activity of Surface Water, Streams and Springs. FRANZ HOCHEDER. Gas-u. Wasserfach, 68: 575–8, 590–2, 610–3, 625–7, 1925. From Chem. Abst., 20: 465, February 10, 1926. Lengthy mathematical discussion with many diagrams, tables, etc.—*R. E. Thompson.*

Water Supply for Textile Mills.—C. L. Hubbard. Textile World, 68: 2891–4. 1925. From Chem. Abst., 20: 466, February 10, 1926. Water clarification and softening for textile mills is discussed.—*R. E. Thompson.*

Amounts of Soap and Builder Necessary to Soften Water of Different Degrees of Hardness. H. B. Robbins, H. J. MacMillan and L. W. Bosart. Ind. Eng. Chem., 18: 27-9 1926. From Chem. Abst., 20: 466, February 10, 1926. Description of most economical procedure to be followed where hard water must be used in laundry work. General conclusion is that soda ash should be added with agitation and a little time allowed for the reaction to take place before addition of soap. Soda ash required varies with hardness of water.—*R. E. Thompson.*

The "OMS" Purifier, a New Clarification Process for Industrial Waste Water. Otto Mohr. Apparatebau, 37: 304, 1925. From Chem. Abst., 20: 466, February 10, 1926. An improved Dorr thickener.—*R. E. Thompson.*

The Behavior of Magnesium Chloride in Boiler Feed Water. J. H. Vogel. Kali, 19: 394–6, 1925. From Chem. Abst., 20: 467, February 10, 1926. Controversial review. Deleterious effects of magnesium chloride in boilers are not caused by splitting of hydrochloric acid, but by other phenomena (cf. Vogel, Die Abwasser aus der Kaliindustrie, Berlin, 1913, p. 250).—*R. E. Thompson.*

The Corrosion of Iron Pipe Lines. Gustav Wiegand. Gas- u. Wasserfach, 68: 731-4, 1925. From Chem. Abst., 20: 467, February 10, 1926. Conditions in German cities described and preventive measures discussed.—*R. E. Thompson.*

Physical Properties of Boiler Scale. G. Paris. Chimie et industrie, Special Number, 138–42, September, 1925. From Chem. Abst., 20: 467, February 10, 1926. Description of various types of scale, their constituents and mode of formation.—*R. E. Thompson.*

Protection of Steam Boilers Against Scale and Corrosion. R. Caillol. Chaleur et industrie, 6: 357-62, 419-24, 469-74, 1925. From Chem. Abst., 20: 467, February 10, 1926. Review and discussion of relative merits and disadvantages of various processes of feed-water purification and of protecting inside of boilers against scaling and corrosion.—*R. E. Thompson.*

The Relation Between Drinking Water and Goiter. W. von Gonzenbach. Gas-u. Wasserfach, 68: 667–71, 1925. From Chem. Abst., 20: 467, February 10, 1926. General discussion of distribution of goiter in Central Europe.—*R. E. Thompson.*

Measurement of the Rate of Flow of Fluids by the Rotameter. W. H. Simmons and F. C. Sutton. Ind. Chemist, 1: 473–4, 1925. From Chem. Abst., 20: 523, February 20, 1926. The rotameter consists of a top-shaped float contained in a tapered glass tube. The liquid to be measured in passing through the tapered tube lifts and spins the float. The spinning prevents float touching walls; hence there is no friction, and height of float adjusts itself to flow which passes through annular space between float and wall of tapered tube, which can be readily calibrated for any liquid. Temperature changes in liquids introduce scarcely any error. Three types are illustrated.—*R. E. Thompson.*

The Principles for the Calculations of Venturi-Meters. OTTO VON KÁLMÁN. Siemens Z., **5**: 473–8, 1925. From Chem. Abst., **20**: 522, February 20, 1926. Description of Venturimeters from Die Wassermesser Fabrik der Siemens und Halske A. G., and the theory and calculations for measuring of water, steam, gas and air.—*R. E. Thompson.*

The Decimal Dropping Bottle as a Technical Titration Apparatus. C. BLACHER. Chem-Ztg., **49**: 959–61, 1925. From Chem. Abst., **20**: 522 February 20, 1926, The nipple of the "normal dropping bottle" is made of proper size to give drops of 0.1 cc. of water solutions. Its advantages for rapid titrations, especially for determination of hardness in boiler feed water, are enumerated. Twelve references included. (Cf. WINTER, Apparatebau, 1923, 161.)—*R. E. Thompson.*

Change in Concentration of Electrolytic Impurities. M. DEKAY THOMPSON. Chem. Met. Eng., **32**: 700, 1925. From Chem. Abst., **20**: 551, February 20, 1926. Equation is derived which gives variation in concentration of an impurity in an electrolyte with time, amount of impurity removed and introduction of impurity being constant for each unit of time. Equation permits calculation of time required to attain equilibrium concentration of impurity, and it is applied to accumulation of impurities in boiler water.—*R. E. Thompson.*

Action of Sodium Chloride Solutions on Ferrous Metals. RENÉ GIRARD. Compt. rend., **181**: 552–5, 1925. From Chem. Abst., **20**: 573, February 20, 1926. Tests on corrosion of cast iron and steel immersed in 20-gram-per-liter sodium chloride solutions showed that: when solution is not aërated both iron and steel lose weight steadily and at approximately the same rates; in aërated solution steel loses weight somewhat more slowly than in non-aërated solution, while the cast iron oxidation products adhere to metal and form protective coating.—*R. E. Thompson.*

Modern Quick-Hardening Cements. C. T. STEPHENS. Commonwealth Engineer, **13**: 89–91, 1925. From Chem. Abst., **20**: 651, February 20, 1926. Short general discussion of high-alumina cements and rapid-hardening portland cements. Differences in composition, manufacture and strength of resulting products stated. Few estimates upon cost and information concerning use of these products in buildings and concrete pipes, included.—*R. E. Thompson.*

Description of Public Water Supplies of Rhode Island. Stephen De M. Gage. Jour. New Eng. Water Works Assoc., 40: 2, 117, June, 1926. Thirty-six public water supplies in R. I. are listed and the following data given for each;—location, population supplied, date of introduction, by whom operated, source of supply, form of distribution, source of power, consumption, and general quality of water supplied.—*W. U. Gallaher.*

New Water Supply System at Tampa, Florida. N. S. Hill, Jr. Jour. New Eng. Water Works Assoc., 40: 2, 128, June, 1926. Rapid growth of Tampa made new supply imperative. Former well supply was highly saline and very hard. Hillsborough River, selected as new source, has dry weather flow estimated at 50 million gallons per day during dry months and 600 to 700 million gallons per day during rainy season. Hardness and color of raw water vary from 200 p.p.m. and 25 p.p.m., respectively, during dry season, to 25 p.p.m. and 200 p.p.m., respectively, during rainy season. Experimental filter plant was operated from August, 1924, to February, 1925. Improvements include intake, combined low and high lift pumping station, treatment plant for softening, decolorizing, recarbonating, and filtering, 30-inch cast-iron force main some three miles long, and three one-half million gallon elevated tanks. Concrete intake chamber in center of channel is 31 feet high in 25 feet of water and has three 48-inch sluice gates protected by 1½-inch wrought iron bar screens. It is connected to suction and screen well by 36-inch cast-iron conduit 225 feet long. Pump suctions are protected by ¼-inch copper wire removable screens. Three 200 h.p. B. & W. water tube boilers using fuel oil (or coal) furnish steam at 175 pounds pressure with 100 degrees superheat. Two 12.5- and one 6.5-m.g.d. De Laval centrifugal pumps operating against 30 feet head and driven by De Laval steam turbines are installed for low lift purposes, and two 10- and one 5- m.g.d. of the same type operating against 2200 feet head have been installed for high lift pumping. Three Wheeler surface condensers, each handling the exhaust from one low-lift and one high-lift pump, use water from the low-lift discharge for condensing. Condenser water is wasted. Two 350 g.p.m. motor driven pumps furnish wash water. The treatment plant has 12 to 15 m.g.d. capacity. Decolorization is aided by addition of sulfurous acid. Water is softened with lime and soda during the dry season. Mixing tanks, eight each for lime and alum, are equipped with bronze propellers operated by 1 h.p. motors. Two tanks are used in series. There are two lime settling basins each with 1 million gallon capacity and 4 hours detention and three decolorizing basins each with ¾ million gallon capacity and 3 hours detention. They may be operated in series or parallel. First half of basins have a simple sludge removal system consisting of 6-inch vitrified pipe underdrains with tees pointing upward the tops even with the basin floor. Open end is closed with vitrified plug with 1 inch orifice in centre. They are designed to stand a small pressure for back washing. Chemicals are carried in solution by concrete troughs from six dry feed Gauntt type machines. Sulfur is burned in two Schutte and Koerting burners of 35 pounds per hour capacity. Gas is cooled, then absorbed in water spray. Vitrified orifice tank is used to proportion solution which is added with alum. Carbon dioxide equipment furnished by Carbondale-New York Company consists of 1200 pounds daily capacity coke oven, scrubber, and compressor. Gas is added through 1½-inch grid in baffled compartment. Filter plant is unusually attractive architectually and is well ventilated and lighted; pipe gallery is unobstructed by pipes etc. Eight 1.5 to 1.75 m.g.d. filters have combined an area of 4800 square feet and contain 18¾ inches gravel which varies from 2½- to 1/16-inch, and 30 inches of sand with effective size of 0.4 mm. and uniformity coefficient 1.6. Wash troughs are concrete. Filters have special strainer system of half-round cast-iron pipes raised ½ inch from the floor to form a long horizontal orifice on each side of pipe. Holes are bored in top to release air. Steel wash tank, capacity 100,000 gallons, is controlled by Ross pressure-reducing valve. Covered filter reservoir with ½ million gallons capacity has been built. Control of pumping station and filter plant is centralized and convenient. A 30-inch cast iron main leads treated water to city where it divides into two 24-inch parallel pipes one-half mile apart. Three one-half million gallon elevated steel tanks in different parts of city reduce peak load at plant. An old 3.5 million gallon concrete reservoir is used for fire service; two motor driven 5 m.g.d. pumps are installed nearby one of which starts pumping water from the reservoir into distribution system as soon as an alarm comes in. Entire system is designed to permit extensions to be made without trouble.—*W. U. Gallaher.*

Rainfall in New England. X. H. Goodnough. Jour. New Eng. Water Works Assoc., **40**: 2, 178, June, 1926. A complete record, with description of gages used, of monthly and yearly rainfall at 337 stations in Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, and adjoining Canada and New York, from the earliest records to 1925 inclusive—*W. U Gallaher.*

The Operation of the Massachusetts "Water Lien" Law. Jour. New Eng. Water Works Assoc., **40**: 2, 161, June, 1926. Ten questions on the law are stated and answered. The law itself is stated and examples given of forms used in connection therewith.—*W. U. Gallaher.*

Report of Committee on Legislative Matters in Massachusetts. Jour. New Eng. Water Works Assoc., **40**: 2,175, June, 1926. Past session of legislature extended the privilege to water companies of obtaining emergency supplies, lengthened the term of bonds for large mains (16-inch or over) to 25 years, and term of bonds for intermediate pipes (6- to 16-inch) to 15 years.—*W. U. Gallaher.*

Data on Zeolite Water Softeners. T. J. Ess. Power Plant Eng., **30**: 16, 888, August 15, 1926. Short description of zeolite softening process. Formulae are given for calculating quantity of zeolite required, area of filter, salt needed for regeneration, etc. Zeolite softened waters may be used in boilers although they contain approximately the same amount of dissolved mineral as before treatment. When nearly run down, zeolite will still remove permanent hardness after it has ceased to remove temporary hardness. Water for boilers of high rating with hardness over 15 grains should have a preparatory treatment with lime and soda before final softening with zeolites.—*W. U. Gallaher.*

Interpretation of Boiler Water Analyses. D. C. Carmichael. Power Plant Eng., 30: 17, 943, September 1, 1926. Boiler waters after soda treatment contain sodium chloride, sodium carbonate, sodium hydroxide, sodium sulfate calcium carbonate, and organic matter. Conversion of sodium carbonate to sodium hydroxide depends greatly on the organic matter, the more of which is present the less hydroxide will be formed. Sodium formate and sodium acetate formed in reactions may suppress formation of hydroxide. Sodium chloride is formed by decomposition of chlorides and sodium sulfate from calcium and magnesium sulfates. Priming is proportional to sodium chloride present. Determinations of chloride, pH, and alkalinity, give rough method for judging proper treatment.—*W. U. Gallaher.*

NEW BOOKS

Chlorination and Chlorine Absorption of Water. Dr. A. Massink. Chemisch Weekblad, 23: 29, 1926. Chlorination of water supplies has been introduced of recent years into Holland and is now coming into extensive use. Two systems are in vogue; the indirect, which is normal practice in America, in which the chlorine reaches main bulk of water to be treated in form of an aqueous solution, and the direct, in which chlorine is applied as a gas in a state of very fine division. The main purpose of present paper is to bring to the notice of those concerned the papers of Abel Wolman in which the fundamental principle of the dependence of the optimum chlorine dosage upon the chlorine absorption of the water was firmly established. In connection therewith is added an instructive review of certain methods in use for determination (*a*) of free chlorine, namely, Froboese's, Olszewski's, Ellms and Hauser's and the Muir and Hale modification thereof, and Winkler's, and (*b*) of chlorine absorption, namely, Wolman's, Froboese's, Bruns's, and Olszewski's. Among many valuable references to the literature, both European and American, such recent American papers as those of Buswell and Boruff and of Ole Forsberg are discussed. While it was found that Olszewski's method of using benzidine and o-tolidin at the pH of approximately 5.6, at which the blue meriquinonoid color is most intense and least fugitive, is capable of yielding good results, yet the preference is given to Muir and Hale modification of Ellms and Hauser method in which is developed, owing to the greater acidity, the yellow holoquinonoid color which is both less fugitive and less closely dependent upon pH control. Olszewski's automatic free chlorine indicator is mentioned with approval.—*Frank Hannan.*

The ABC of Hydrogen Ion Control. W. A. Taylor. Catalog of LaMotte Chemical Products Company. This catalog gives a treatise on the colorimetric determination of hydrogen ion control as well as listing materials and equipment. It contains a non-technical discussion of hydrogen ion concentration and pH values, a technical discussion for the chemist, bacteriologist, engineer, etc., and the application of pH control to over twenty different types of work. In water purification pH control has been widely adopted. Coagulation takes place at a definite pH value, which is different for different waters. By determining the optimum pH value for a given water, which can be done by a few simple tests, the smallest amount of alum necessary to give the best and quickest floc is used at all times and no alum is wasted. The use of alum or acid tends to decrease the pH, and it is in many cases necessary to add alkali after coagulation to prevent corrosion of the distributing system. pH control is also of great value in the softening process, whether lime and soda or artificial softeners are used. The pH value of the brine solution has a marked effect on the efficiency of regeneration of zeolites.—*A. W. Blohm.*

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THE BUFFALO WATER WORKS[1]

BY GEORGE C. ANDREWS[2]

The inhabitants of a modern city are so accustomed to securing water for all purposes simply by turning on a faucet that they seldom realize the amount of study and work involved in obtaining such a supply, and are also ignorant of the progressive development of and the large amount of money expended on their water works system.

Buffalo is fortunate in having an ample supply of water in Lake Erie easily accessible, but the development of its water works system has involved an expenditure of nearly twenty-six million dollars, which covers the cost of a progressive enlargement of the system from 1849 to the present date.

The history of the Buffalo Water Works may well be divided into three parts.

1. The development of the system based on the erection and operation of the Massachusetts Avenue Station with its intake and tunnels from 1852 to 1903.
2. The planning and construction from 1903 to 1915 of the Colonel Ward Pumping Station and the new intake at the head of the Emerald Channel with the necessary tunnels.
3. The improvements in the operation of the stations and the reduction of water waste with the view of making possible the con-

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[1] Presented before the Buffalo Convention, June 8, 1926.

[2] Consulting Engineer, Water Commissioner, Buffalo, N. Y., 1916–1926.

struction of a modern filter plant of ample size at a reasonable investment, and the construction of this plant. This period covers the past ten years.

EARLY CONSTRUCTION

The earliest record of any municipal supply in the city of Buffalo is of 1831, when four cisterns of ten thousand gallons each were built. They were filled with water from the Erie Canal and were used for fire protection.

The Jubilee Springs Water Company, a private organization, was formed shortly after this. Their supply was obtained from springs located 2 miles north of the city and the water was distributed by means of log pipes.

Wells and springs were the sources of water supply up to 1852, when water was furnished from the Niagara River by the Buffalo Water Company, a private corporation organized in 1849. This company erected a pumping station on the easterly side of the Erie Canal at the end of Massachusetts Avenue, the site of the present Massachusetts Avenue Station, and took the water from the Niagara River through a tunnel under the canal. The system had two high pressure pumps, a seven million gallon reservoir, approximately 600 feet by 260 feet by 18 feet, and 13 miles of cast iron pipe from 4 to 16 inches in diameter.

From 1852 to 1869 this privately owned company and the Jubilee Water Company furnished the water supply to the city. In 1868 the city took over these plants and operated them under three commissioners until 1893, when the water system was made a bureau of the Department of Public Works.

Immediately after the city took possession, the old plant was found inadequate and in 1869 competitive plans for the improvement of the water system were received. One provision of the competition to be considered was the possibility of using the flow of the Niagara River to operate the pumps. First prize was awarded to Thomas Dark Sr., who submitted a plan for an intake in the center of the river opposite the station with a connecting tunnel driven through rock.

His plan also included a 21.9 million gallon reservoir and, it is interesting to record, a 28 million gallon per day filter plant, the filter area being 51,684 square feet, with a rate of filtration of 3 pints per square foot per minute. This was the earliest recommendation of filtered water for the City of Buffalo. The plan of building a new intake and tunnel was adopted and in 1870 the contract for building them was awarded for the sum of one hundred seventy thousand dollars to Clark & Douglas. Mr. Dark, until the time of his death in 1915, was a constant advocate of filtration and a thorough student of the affairs of the water system. It is of interest to state that a grandson of Mr. Dark constructed in 1909 the Emerald Channel intake and connecting tunnels.

The original plans called for an intake pier with openings and gates, 45 by 25 feet at the bottom with ½ inch batter per foot. This pier was to enclose a vertical shaft located 700 feet west of Bird Island pier and to be connected with the pumping station on shore by a tunnel through the rock, 6 by 6 feet in size.

Difficulties were encountered, the size and location of the pier were changed and it was not until 1875 that the work was completed. Two contractors abandoned the work and the tunnel was finally completed by day labor. The total cost of intake and tunnel was $519,403.

The intake, as finally built, was 118 by 22 feet at base and 32½ feet high with a hexagonal top 36 by 16 feet. A sloping nose, or ice and water cutter, projected up stream. On the sides of the pier are ice shields made of steel plates 1 inch thick, projecting 2 feet from the pier and extending to within 2 feet of the bottom of the river. The shields have gates opposite the intakes that can be raised and lowered to prevent ice from entering the shafts. There are two inlets 5 feet by 3 feet with sills 8 feet 9 inches below mean lake level. A 6-foot circular shaft connected the intake with the tunnel, and the capacity, with water 3 feet below mean lake level, was one hundred fifteen million gallons per day.

The tunnel from intake to pumping station was 1340 feet long and was from 4½ to 10 feet by 9 feet in size. As originally designed, it was to be an oval brick-lined conduit, but as constructed, it was unlined.

Great quantities of sulphur water came through the seams of the rock at one place and there an iron shell 6 feet in diameter was placed to shut off the flow. The capacity of this tunnel is 125 million gallons per day. No compressed air was used in construction.

In 1895 a second tunnel was started from the station to the intake. This tunnel was eight feet square and driven through rock at practically the same level as the earlier one. Compressed air was used in construction and work was completed in 1897.

During the period from 1889 to 1894 another major improvement to the system was the building of the Best Street Reservoir. This reservoir occupies an entire city block bounded by Jefferson, Best, Masten and Dodge Streets. It is 1472 feet long, 597 feet in width and has a capacity of 116,200,000 gallons. When full, the water elevation is 685.23 above mean tide at New York and 112.43 feet above mean lake level.

The pumping station was gradually enlarged and improved. In 1903 the pumping capacity was 187 million gallons per day. Buffalo at that time had long been noted in the water works profession as an excessive user of water and in the year ending July 1,1903, the pumpage was 42,624,000,000 gallons, a daily per capita 324 gallons.

Until 1891 water was supplied to all sections of the city at one pressure. However, the extension of the city to higher land in the northeast made it necessary to pump at a higher pressure for this section, and piping and valves were arranged so that the city was divided into two pressure systems, the higher having a pump pressure of from 75 to 95 pounds and the low, or reservoir service, a pump pressure of 50 pounds. Gradually this area grew in extent until since 1921 only the southeastern section is supplied at the reservoir head.

In 1903 the system consisted of the Massachusetts Avenue Station, the Niagara River intake with two tunnels, the Best Street Reservoir and distribution system. Plant investment at this time was $7,388,000.

DEVELOPMENTS BETWEEN 1903 AND 1915

This year marks the second period of the development of the Department. In 1902 Buffalo experienced a typhoid fever epidemic which aroused public opinion to the needs of a better water supply. Two reports were made in that year; one of the Department of Public Works by Rudolph Hering, Gen. George S. Field and Col. Thomas W. Symons, recommending the construction of a new intake in the Emerald Channel at the junction of Lake Erie and Niagara River approximately 10,400 feet southwest of the old intake, to be connected to the shore by a tunnel 12 feet by 12 feet 6 inches and 6651 feet long, where a new pumping station was to be built, the present Colonel Francis G. Ward Station, with a further tunnel 9 feet by 9 feet 4 inches and 4286 feet long from the shore shaft to the Massachusetts Avenue Station; the stations to be so equipped and connected with the distribution system that either station could supply the city if necessary.

The other report by George W. Fuller was given to the Health Department and covered the typhoid fever epidemic, investigation of the sources of pure water and a favorable opinion on the plan of the consulting engineers.

These reports were subject to long debate in the council chamber and in the press, but the work was finally authorized and plans started in 1906.

In June, 1907 the contract for the tunnels and the new intake was let and work commenced that season.

The new intake, since designated the Emerald Channel intake, has operated very successfully and is briefly described as follows: Situated at the head and center of the Niagara River with water normally 28 feet deep: it consists of two concentric steel shells, one 70 feet in diameter, the other 110 feet in diameter, with the space between filled with concrete. The shells were sunk onto a level concrete footing and rip rap 8 feet deep was deposited inside and outside the shells. Within the intake a 6 inch concrete layer was placed over the rip rap. In the center a 13 foot shaft was sunk through the rock 40 feet to the tunnel and it was continued upward 31 feet 6 inches above the rip rap by means of a steel shaft of the same diameter.

The outer shell has twelve ports 6 feet by 6 feet in size, equally spaced with their sills 20 feet below ordinary lake level and equipped with gates so that they can be controlled from a balcony in the intake.

The flow of water through the steel shaft to the tunnel is controlled by four openings 5 feet 3 inches by 6 feet equipped with gates.

The superstructure encloses the operating gallery, chlorination room and living quarters. This intake was put in operation May 12, 1913, and in August, 1914, a chlorinating plant, the first chemical treatment of the city's water was placed in operation. In October, 1924, the chlorinating plant was placed on shore, the building locked tight and the intake has since served its purpose without manual attention. For the period from 1913 to 1924 two men were kept constantly at the intake to operate the chlorinator and to regulate the gates. This intake has only at rare intervals been bothered with either slush or anchor ice. During the winter the lake is usually frozen over up to the intake.

The tunnels from the intake to the shore and from the shore shaft to the Massachusetts Avenue Station were started in 1907 and completed in 1913. The former is 12 feet by 11 feet 6 inches in size

6651 feet in length, and the latter is 9 feet by 9 feet 4 inches and 4286 feet long. Both tunnels were driven through limestone with inverts at elevation 506.7 and are concrete lined. The maximum capacity of the intake and main tunnel is estimated at 450,000,000 gallons.

In July, 1909, the contract for building the new pumping station was awarded and it was completed and put in operation in 1915. This plant is one of the largest and most completely equipped in the country.

Briefly, it consists of an engine house 95 feet by 364 feet, containing 5 thirty million triple expansion engines, 3 centrifugal three thousand gallon per minute high pressure fire pumps and foundations for three additional pump units; a boiler house 100 feet by 200 feet containing eight B & W. boilers, 750 h.p. each, with foundations for eight additional, equipped with McKenzie traveling grate stokers and Foster superheaters. Besides the above, the building encloses valve and pipe room, Venturi meters, feed pumps, electric generators, intake well, offices, storeroom, machine shop and chemical laboratories.

In 1908 the Kensington water tower was erected to serve as a relief on the high services. This structure is a steel cylinder 40 feet in diameter, 85 feet in height, surrounded by an ornamental stone and brick tower. Its capacity, when filled, is 704,970 gallons and the base is 106.31 feet above normal lake level.

During the period from 1903 to 1915 the Massachusetts Avenue Station was practically rebuilt and re-equipped, so that in 1916 the water plant consisted of two intakes with tunnels, two pumping stations with a combined pumping capacity of 330,000,000 gallons per day, one reservoir, one water tower and distribution system, and was valued at $17,219,061.03.

WATER WASTE REDUCTION

In 1915 the pumps at the new Porter Avenue Pumping Station which was later named the "Colonel F. G. Ward Pumping Station" in memory of the late Commissioner of Public Works, under whose administration it was initiated and constructed, were first put in regular operation and since that date the station has been continuously operated.

By the completion of the Ward Pumping Station it was no longer necessary to depend entirely upon the pumps at the Massachusetts Avenue Station and the pumpage from this station has gradually decreased as the demand for water has diminished during the past ten years.

From 1916 to 1921 the efforts of the Bureau were devoted exclusively to improving the system, decreasing the consumption of water and increasing the efficiency of the pumping plants, so that it would be possible to design and erect a filtration plant of sufficient size and at a reasonable cost as a final step in improving the water system.

In 1916 Buffalo had a magnificent water system, but its operation was lax and inefficient in nearly every respect. This included financial methods, the system of billing and collection of water rates, inspection, maintenance and extension departments, and the operation of the pumping stations. The water consumption was at a tremendous figure, in 1916 the total pumpage being over 61 billion gallons or a daily per capita consumption of 339 gallons. The stations were operating without coördination and little or no efficiency was being striven for in their operations. The commission form of government had been introduced in 1915 and a body of five representative citizens had been elected to govern the affairs of the city.

Shortly after their inauguration the speaker became Water Commissioner and took steps to improve existing conditions. Satisfied that a tremendous waste of water existed, a pitometer survey was made of the entire city, with the result that the consumption was reduced to less than fifty billion gallons in 1918. Realizing that the effect of the pitometer survey would soon be lost if it was not followed up closely, a permanent pitometer department was organized and the consumption data covering the various sections of the city, secured by the first survey, were kept as a guide for their work.

The original survey showed many sections where there was household wastage to so great an extent that the night rate was 80 per cent of the average daily rate. Such sections were marked for special inspection and frequent re-measurements. The total pumpage, as shown, decreased each year until in 1925 the daily per capita consumption had been reduced to 214 gallons.

Where persistent water wastage was encountered, meters were installed. The number of meters has been increased from 4219 in 1916 to 14,945 in 1925. While our consumption is still high compared with other cities, it is well within the capacity of our pumping plants and very little advantage would be obtained by reducing it lower at the present time. It is the aim of the Department to hold the total pumpage at approximately the present figure, notwithstanding the normal growth of the city and this means that the per capita consumption will be reduced year by year; so far, there has been little difficulty in doing this.

PUMPING STATION IMPROVEMENTS

In 1915 the total pumping capacity of the Ward Station was 150,000,000 gallons and that of the Massachusetts Avenue Station 180,000,000 gallons, and the daily average pumpage approximately 170,000,000 gallons. As the result of the water wastage campaign it was possible to do the bulk of the pumpage at the Ward Station on account of its more economical equipment. At the present time it is possible to supply the entire city for 80 per cent of the year from this station. However, as the Massachusetts Avenue Pumping Station would rapidly deteriorate if shut down, it has been considered advisable to maintain a skeleton crew at that point and operate one pump throughout the year.

When the pumpage was at its maximum it required approximately one ton of coal per million gallons pumped and as the pumpage was reduced the coal consumption per million gallons increased slightly, due to using a larger percentage of coal consumed for heating and other incidental purposes. To reduce this coal consumption a survey was made in 1917 of the two stations and certain recommendations for their improvement made.

The steam piping layout at the Ward Station, which is equipped with eight 750 h.p. B. & W. boilers set in line, consisted of an independent steam header at the front and back of each boiler. These two headers extend to the pump well between the boiler house and the pumping station and there drop into two independent steam headers running parallel to the five triple expansion pumps. These headers were placed on steel I beams about ten feet above an open suction well. One header supplied two pumps and the other header supplied three pumps, there being no inter-connection between same, so that in case of the failure of one header either two or three pumps were put out of commission. This layout had six 16-inch blank ends and sixteen connections from the boilers. A plan was drawn up, making a modern loop steam line layout properly equipped with valves, so that steam would feed into the header in both directions, and in case of the failure of any boiler or pump it was possible to isolate them by closing two valves and still keep the other four pumps and seven boilers in operation. This change was made while the plant was in operation and upon its completion the coal consumed at the Ward Station dropped from 1.2 tons per million gallons to approximately 0.9 ton, and the saving in coal in three years' operation paid for the change.

STRENGTHENING THE DISTRIBUTION SYSTEM

During the time of high consumption complaints were made as to the lack of water pressure in various parts of the city, especially in the northeast and southeast sections which are furthest from the station. To improve this condition experiments were made in cleaning certain sections of pipe and in 1920, 1921, 1922 and 1924 most of the large mains which had been in service twenty years were cleaned. The result of this was that the water pressure in the southeast section, which is connected with the Best Street Reservoir, was increased from 15 to 28 pounds.

In the enlargement of the Massachusetts Avenue Pumping Station, the discharge mains leading from the station were carried under the New York Central tracks and 50 feet up a steep bank to Front Avenue. Owing to complications with the New York Central Railroad no permit could be secured or agreement made with them which would permit us replace the old mains under their tracks and as the number of pumps was increased and the sizes changed a net work of pipes had been laid in the slope and the street. When the old station operated alone there was constant danger of these pipes breaking and flooding out the station. It had been equipped with a large number of valves to minimize this danger.

At the time of changing the city from one service to two services additional valves and piping were installed so that there were a great number of valves to be operated in changing the pumps from high to low service or to be operated in case of a break; in fact, any trouble there usually called out the entire number of maintenance men in the Department. A study of the valves and pipes was made and in 1921 the main valves in this layout were equipped with electrical opening and closing mechanism operated from a central switchboard. This equipment served a twofold purpose; first, it allowed the valves to be opened and closed daily, keeping their mechanism in good condition, and second, in case of breaks in the line or shift from one pressure to another, valves could be operated from the switchboard.

HIGH PRESSURE FIRE SYSTEM

A high pressure pipe line for fire protection, equipped with hydrants, was laid in 1897 and gradually extended, until in 1916 it protected the high valued area bounded by Huron, Franklin, Ellicott Streets and the Buffalo River. Water was supplied at 300 pounds pressure by fire boats. Upon the recommendation of the fire chief in 1920 three 3000 gallon per minute centrifugal pumps, driven by steam turbines, were installed at the Ward Pumping Station and an independent 20 inch line laid from the station connecting with the system at three points; Huron and Pearl, at Eagle and Pearl and at the Lower Terrace and Main Street. The old hydrants were removed and replaced by the modern high pressure type, equipped with four 3½-inch nozzles. The change allowed more freedom of movement of the fire boats, made the system instantly responsive to calls for service and allowed the system to be kept constantly filled with water, as all pipe was laid below the frost line. This work was completed in 1922 under the supervision of the Bureau of Water.

WATER CHARGES

The financial affairs of the Water Department in 1916 were found to be in a very unsatisfactory and unbusinesslike state and an operating deficit of over $200,000 had been incurred in the five preceding years; maturing bonds were being renewed, and interest and sinking fund requirements on the new bonds were increasing faster than the increase in receipts. A thorough study was made of this matter and a new rate schedule was recommended.

The bulk of the services were, and still are, on the flat rate basis and the meter rates were so extremely low, two cents per thousand gallons, that the installation of meters gave no added income. A report was made recommending an increase in flat rates of approximately 40 per cent and a three step sliding scale for meter service. The lowest charge for metered water was five and one-third cents per thousand gallons. The report was adopted by the Council and the new rates placed in effect September, 1920. The rates gave a surplus of from three to four hundred thousand dollars a year after paying operating charges, fixed charges and sinking fund deposits. This balance has been used for paying maturing bonds and for making pipe line extensions.

FILTRATION

The need of filtered water had long been recognized in Buffalo, but the tremendous pumpage, due to the excessive waste of water, had made the cost prohibitive. The size of a filter plant where there is no large storage reservoir is directly proportional to the maximum demand and the operating cost is partially proportional to the yearly pumpage. In February, 1917, our maximum daily demand was 257,593,000 gallons and for the year ending June 30, 1917, the total pumpage was 61,470,594,000 gallons. These figures were reduced to a maximum daily pumpage of 206,580,000 gallons and a total pumpage of 51,687,000,000 gallons for the 1919–1920 fiscal year and water waste was under such control that definite figures for a suitable plant could be recommended.

The industrial depression of 1921, with the resulting unemployment, brought the question of making permanent public improvements to the fore, and the City Council put the question of building a filtration plant of a normal capacity of 160,000,000 gallons per day at an estimated cost of $4,000,000, to a vote in November, 1921. The vote was favorable by a substantial majority and an engineering force was organized in January, 1922.

The Buffalo filter plant will be described in detail in one of the papers to be presented at this convention and I will mention it only briefly here.

It is located on Jersey Street just south of the Ward Pumping Station and consists of a covered raw water conduit 506 feet long 12 feet by 12 feet in size connecting the tunnel from the Emerald Channel Intake with the low lift pump station of the filter plan. The low lift pump station is 50 feet by 93 feet in size equipped with five centrifugal electrically driven pumps of a total capacity of 240,000,000 gallons per day, with a lift of 17 feet; a coagulating basin 425 feet by 325 feet with a three-hour detention period; forty filter units 33 feet by 50 feet of a normal rate of filtration of 4,000,000 gallons per day, capable of 50 per cent overload; a filtered water reservoir 515 feet by 330 feet with 18,000,000 gallons storage capacity directly underneath the filters, so built that forty additional units can be added when water needs demand same; a filtered water conduit leading to the pump well of the Ward Station and connections made with the pump well and the tunnel leading to the Massachusetts Avenue Station; a head house containing the wash water tanks, chemical feed and chlorine machines, laboratories, offices, etc.

The construction was carried on mainly by contract. The first contract consisting of excavation, substructures, conduits, etc., was let in August, 1922, and work started that fall. Other contracts embracing valves, gates, pumps, electrical equipment, filter equipment, piping, sand and gravel, superstructures, etc., to the number of twenty-five were let at various times. It is interesting to note that in the operation of the filter plant it has only been necessary to make two changes in the pumping equipment of both the Ward and Massachusetts Avenue Stations; first of these, was changing the condensers on the triple expansion pumps from jet to surface type; the other was an extension of the suction pipes of the pumps of the Ward Station so as to get the full benefit of the clear water reservoir capacity. The plant, as designed, has a normal capacity of 160,000,000 gallons per day, but all conduits, pump connections and filtered water reservoir have been built so that the capacity of the plant can be increased 100 per cent by enlarging the coagulating basin and building the forty additional filter units and replacing the smaller pumping equipment with larger units so that eventually the Buffalo filter plant is likely to be the largest individual filter plant in the country. The cost to date, including all engineering fees, force account and balances due on uncompleted work is $3,736,000, which will be practically the cost of the completed work.

In the design of the plant consideration was given mainly to substantial construction, economical operation, not only of the filter plant, but also in conjunction with the pumping stations, attractiveness of appearance inside as well as outside, and also to utilizing the surrounding grounds in a general water works park development. These conditions, we believe, have been met to a marked degree and at a most reasonable expenditure of money.

With the completion of the filter plant, the Buffalo Water Department will consist of two pumping stations with a combined capacity of 330,000,000 gallons, two intakes with tunnels, one reservoir with a capacity of 116,200,000 gallons, one water tower, one filter plant with a maximum capacity of 240,000,000 gallons per day and distribution system sufficient for its needs. The plant investment, as of April 1, 1926, was $23,500,000.

With the proper operation this plant should not only give wholesome clear water, but also should be sufficient for the needs of the city, at its present rate of growth, until 1935.

A LARGE ELEVATED STORAGE TANK AT CHARLESTON, S. C.[1]

By James E. Gibson[2]

The many advantages obtained by the use of elevated tanks and standpipes to reinforce the distribution system have not been fully appreciated by the water works fraternity. The earlier tanks were entirely too small to offer any service along this line, but in recent years the quality of workmanship, material and design has so much improved that they now offer a very great advantage in this work, particularly in view of the high cost of laying large mains in improved streets with the attendant interference of traffic, etc. We propose to give you a concrete case at Charleston, S. C.

Here we had the direct or Holly system. The pumping station is located about 12 or 13 miles from the center of distribution; pumps are of the fly-wheel type. The pumping mains consist of a 24-inch cast iron line extending from the pumping station to the city and a 20-inch continuous wood stave pipe line extending from the pumping station for two-thirds of the distance to the city. The consumption within the city proper is fairly regular, particularly the domestic consumption, but just outside of the city limits between the center of distribution and the pumping station are large fertilizer, oil refining, lumber and manufacturing plants which require large quantities of water. While we have insisted upon their taking this water at a relatively uniform rate and installing tanks to supply their peak demand, it is not always possible for them to do this, with the result that their demands for water have caused a rather erratic pressure condition in the city proper. The peak demand was about 10½ million gallons per day; the minimum 3½ million gallons between midnight and six o'clock in the morning; and the average about 5½ million gallons. The maximum pumping pressure at peak load was 125 and the minimum 50 pounds. It will be appreciated that to maintain the 125 pounds throughout the twenty-four hours would have caused excessive pressure at the time of minimum consumption. The result was that we had to operate the pumping station under a varying pressure. If, for any reason, a heavy draft had come other than at the hours normally expected, the pressure in the city would be abnormally low at such times.

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[1] Presented before the Buffalo Convention, June 11, 1926.

[2] Manager and Engineer, Water Department, Charleston, S. C.

Some two years ago we considered installing additional mains, but the estimated cost was in excess of the benefit to be obtained, for we realized that their installation would not eliminate, but would merely reduce, the extreme difference in pressures. We considered, therefore, the question of placing a large standpipe or tank downtown near the center of distribution. By the use of a mass diagram based upon a week of high consumption as recorded by meter charts, showing the flow through the pumping main at the pumping station and at the city limits, we found that with a storage capacity of about 1½ million gallons near the center of distribution, we could maintain a uniform pressure within the city by pumping at a uniform rate under a uniform head. We began to investigate the size of tank required to give us this quantity and found that two tanks 56 feet in diameter approximately 120 feet high, or one tank 80 feet in diameter, 120 feet high, would give us the desired results. Upon taking this matter up with a number of the tank builders, we found that the 80-foot diameter tank was feasible and that the cost was less than that of two tanks. Early in 1925 contract was let to the Chicago Bridge & Iron Works for an elevated steel tank with ellipsoidal bottom, having a total height of steel work of 115 feet.

A site which we thought would offer suitable foundation for a tank of this size was purchased. The piers supporting the column loads were built of concrete, pyramidal in form, with their base 5 feet below the average natural surface. The total height of the tank above average street level is 130 feet.

The question as to the safe bearing value of the soil was one of the most interesting points. The following is a log of the holes drilled at the site:

12 inches top soil
18 feet of yellow sand, dry
9 feet of tough dry clay
4 feet of light yellow sand containing small shells and water
14 feet of dark gray sand and water
10 feet of clay mud and shells directly on top of marl 56 feet below surface
Thickness of marl in this section varies from 300 to 600 feet.

Tests for bearing values were made by means of a weighing platform surmounted on a square timber post, having an area of approximately 0.5 square feet. Tests were made at three different locations none of which however were within the area to be occupied by the foundations of the tank. Results of the tests are given below:

LOADING, POUNDS PER SQUARE FOOT	SETTLEMENT IN INCHES AT LOCATION		
	No. 1	No. 2	No. 3
4,000	1.125	1.00	0.25
6,000	1.800	1.125	0.60
10,000	2.64	1.920	1.56
12,000			1.92
14,000			2.08
16,000			2.52
16,000	Final after twelve days		2.64

Minimum period between loading twenty-four hours.

No rain occurred to soften the soil during period of test.

Locations 2 and 3 are more representative of the soil conditions upon which the tank will stand.

Thus, the settlement varied from 0.25 up to 2.6 inches, depending upon the load and the location. The tests indicated that there would be some settlement of the concrete foundation, but the question was to distribute properly the load on this soil so as not to exceed 2¼ tons per square feet, including live and dead loads and foundations. Pyramidal form of construction for column piers was selected and in order to keep both the yardage and the stresses in the concrete within reasonable limits, deformed steel bars were used. I wish to say at this point that I think it would be advisable for the tank builders to give the foundation greater consideration, since this feature of the design has considerable influence on the final cost of the entire structure.

After the tank was completed we filled it and took observations on each column pier, noting the settlement as the tank filled. The maximum settlement of any one pier was 1.656; the minimum 1.333; average 1.512 inches. We had anticipated minimum settlement of an inch and a maximum settlement of 1.5 inches. We then emptied the tank for the placing of bitumastic enamel on the inside, which work was completed the latter part of last month. The second series of levels indicated that the foundations rose on the average of 0.374

inches about five weeks after the tank was emptied to apply bitumastic enamel. Another series of levels, taken when the tank was filled for the second time and just prior to its being placed in service, showed the foundations to have settled back again to the same elevation as occurred under full load the first time. We understand that this practically agrees with another case, where, after taking the load off after initial filling, the foundation tended to rise and on the second filling, the settlement exceeded the first slightly, after which no further movement occurred.

Quite a unique feature of this standpipe, we consider, is the overflow trough, and it must be borne in mind that Charleston has a very mild climate and only occasionally do we have ice. I have lived in Charleston now for nine years during which time we have had ice formed on our storage reservoir only once and then of a thickness just sufficient to bear your weight. During the usual winter we get only a very thin skim of ice and only then in the more exposed places. The tank is built in a residential section that is not yet entirely built up. If it were not for the overflow trough, future residences might be damaged by water being washed over the edge of the tank by high winds. The overflow trough constructed on the outside edge of the tank is 18 inches deep and 18 inches wide, and its outer edge projects to a minimum height of 6 inches above the inner edge of the tank. This trough also serves as a stiffening girder around the top to maintain the tank in its true shape in the same manner as the balcony girder. Leading from this wash water trough down one side is a 12-inch conductor pipe which will carry this water to the sewer or drain. By this means we hope to preclude complaints from property holders caused by any overflow that may occur by too continuous pumping or by wave action. This type of construction, of course, would be impossible in a country where ice forms every winter and for a considerable time.

You will note that we have not covered the tank. This probably will be criticized by some, but we gave the matter considerable thought, and the tank is designed so that at any time in the future we can put a roof on it. We have, however, taken the precaution to have all plates and members at the top turned on edge to discourage the alighting of large birds on this tank, as we understand that a bird must have sufficient grip to be permitted to alight and retain its position.

The design of the tank was based upon the following stresses:

Working stresses in plates and members, bottom of tank, and first ring where columns of tower join shell of tank	13,000 pounds per square inch
Vertical plate above bottom ring	18,000 pounds per square inch
Steel and structural tower	18,000 pounds per square inch
Bearing value on soil	2¼ tons per square foot

The total weight of the tank when full, including foundations, is 22,120,000 pounds; the weight of the steel work 1,550,000 pounds; and the weight of the water 17,170,000 pounds; calculated wind load 100 pounds per square foot on one-half the projected area of the tank and bottom. The center or riser pipe is figured to carry one-sixth the total load of the tank, or approximately 3,200,000 pounds; columns are Bethlehem H section and all diagonal tension members and struts are of standard structural steel shapes. Minimum thickness of any plate in tank shell and riser pipe is ⅜ inch, and in the overflow trough ¼ inch. Bethlehem H sections were selected for the columns because of their simplicity and accessibility of all surfaces for painting.

With the tank in service, it is our intention to operate our pumping station units at a uniform speed and pressure throughout the twenty-four hours and maintain downtown on the street mains a pressure varying from 50 to 40 pounds. The tank is designed to cover a maximum demand for any one day in the week, based on a weekly pumping record.

We have purchased sufficient land at the site of this tank for a second tank of the same size when it becomes necessary.

DIVERSION OF MUNICIPAL WATER WORKS FUNDS[1]

D. C. Grobbel:[2] The growth of urban population in America in the past decade or two has very much increased the problems of city government. With the need of improvements in municipal activities has come a large increase in the rate of taxation. To keep this rate down has been the object and aim of every municipal administration. This aim may be prompted by political expediency or an honest effort to lighten the burden of the home-owner, the merchant or the industrialist.

Constant surveys are made to discover new ways and sources for obtaining funds without directly levying through taxes. One of the methods of obtaining such funds has been to sequester the profits, if any, of the only general utility enterprise that most of the American cities have, namely, that of supplying water.

The justice of such sequestering of money earned by municipal water utilities has been stoutly contested by practical water works men, but recent years have shown an increased tendency to make use of this method of obtaining funds for other municipal operations.

The basis for the authority to appropriate such surpluses that may occur is born in the erroneous idea that a municipal plant belongs to the tax paying citizens of a municipality, disregarding the actual fact that there is a distinction between the water consumer, namely, he who purchases services and water from the utility, and the general tax payer. That such distinction exists must be apparent to any who give thought to the operation and financing of a municipal water works plant, and this distinction has been upheld by courts and utility commissions. A study of the finances of approximately two hundred water works in the United States shows that practically all of these works are self-supporting, that besides the payment of the operation and maintenance expenditures, sinking fund on bonded debts and interest charges must also be met from the earnings of these works. The water consumer of these works, therefore, provides the works and although the title may be in the municipal corporation, the fact, nevertheless, exists that the works are paid for through water rates by the water consumer.

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[1] Topical discussion presented before the Buffalo Convention, June 7, 1926.

[2] Assistant Secretary, Board of Water Commissioners, Detroit, Mich.

The Maine Public Utility Commission, in the case of Knowlton vs. Farmington Village Corporation (P. U. R. 1918E, p. 884), a case wherein the funds of the water works were used for other municipal operations, states this very plainly. In rendering its decision, the Commission says that,

> The fallacy of the theory that this water service is furnished by the respondent as a corporate entity, just as it might furnish fire department, police or public school service, lies in the fact that the Farmington Village Corporation does not actually provide this service. It holds the legal title and operates the plant, but as a corporation it never paid a dollar for the property, and does not expect to. It collects the revenues from the water takers and disburses them. The consumers not only have paid all that has been paid on account of the cost of the water works, but very much more. They have paid in water rates the actual cost of that service, and during several years past, the cost of all other corporate activities of the Village Corporation.

Where such appropriating of water works funds is practiced, it is usually based upon the fact that when the works was first constructed, or purchased, the funds for the cost were either raised through a tax levy or by pledging the credit of the municipality, namely by bonds. In other words, the responsibility for the municipality having a water works was placed upon the whole tax paying citizenship and not only upon those estimated as the possible custtomers of the utility. Where this is true, it must be borne in mind that the municipality only loaned its aid as an established financial agency for the purpose of securing a most needful utility for the community.

Coincident with the municipal legislation regarding the securing of a water works, or even before construction is started, or purchase of an already constructed but privately owned plant is consummated, the question of the water rate that is to be paid is discussed and efforts made, though not always successful, to adopt such rate that will not only make the works self-sustaining, but ultimately also to retire or pay the indebtedness incurred in establishing the water system. The rules regarding what such rate should be are well established, not only in the text books on water works practice, but also, and with more weight, by the utility commissions and the courts in the various states.

The earnings from the water rates for a municipal plant should be such as to provide for operation and maintenance, depreciation, taxes and interest on the funds invested by the municipality. There can be no discussion on the matter of operation and maintenance and depreciation. On the matter of taxes, it is uniformly held by authorities on municipally owned utilities that the non-levying of taxes against a municipal utility is discriminatory in favor of the user of the utility. True, where the municipality foregoes the levying of taxes, the utility is usually supposed to furnish a quid pro quo in the shape of free service and water to a multitude of municipal operations, but, here again, there may be and almost always is a discrimination against the water consumer, who is thus compelled through the payment of the rates to provide for things that should have been paid through taxes by the tax-paying citizenship of the municipality.

There remains, therefore, the interest on the municipal investment. This brings up the question of public policy which the municipality may wish to pursue in the operation of its water utility. Ordinarily, a water works is acquired for the benefit of the citizenship consumer. Such benefit may be a low rate, or a more adequate or pure supply at a low rate. Indeed the benefits of low rates or an adequate supply are the usual and persuasive inducements presented to the citizen to establish a water works or purchase an established one.

Therefore, the municipality must determine whether the water utility is to give service at cost or service for profit; if the former, it is acting on the theory that a municipal government, or for that matter, all government exists to serve the general welfare of the public. If, however, the municipality desires to enter the business field by the establishment of a profit making water works, it stands to reason that such business must be carried on under the rules, laws and principles established for such business. Moreoever, such business must be conducted for the benefit and welfare of the inhabitants of the municipality.

Where the municipality decides to give water service at cost, such plan can only be a theoretical one, for it follows that in either a fast growing, or a decreasing community, there can be no stability in the rates and consequent earnings from these rates. There must be a constant shifting in the expenditures and earnings. True, there may be communities that do not change in their growth of population, commerce or industry, but these are few. In such communities, constancy in earnings and expenditures of water works plant may be attained.

In considering the service for profit policy, as stated before, the municipality is under the same rules of business as a private owner, with the added obligation that it must conduct the business so that it redounds to the public welfare. Such service must produce earnings which will cover all legitimate operating and maintenance expenditures, depreciation, interest on the bonded indebtedness and a return on the fair value of the plant. The latter item must partly be used for a sinking fund to retire the usual bonded indebtedness and the remainder of the profit distributed or placed in reserve.

It is the distribution of this surplus profit that may be present that raises the question before this body. As has been noted, there exists a difference between the citizen taxpayer and the citizen water consumer. To distribute the surplus earned to the citizen taxpayer in the shape of added police, fire or sanitary protection, is manifestly wrong, because an additional tax burden is placed upon the water consumer as a class, making the latter subject to double taxation. Again, there is no relation between such municipal operations as fire protection and other municipal operations which redound to the benefit of the general taxpaying citizen and for the support of which tax levies are made, and the consumption of the water by the water rate payer.

Where, then, is this surplus, if any, to be placed? Ordinary business prudence, it would seem, would prompt the municipality to take note of any changing conditions in managing the affairs of the water works, adopt improved devices in order to bring the plant to a high state of efficiency, and secure such equipment as will tend to greater economy in operation, in a word, use the surplus to secure such betterments in the works as a prudent and intelligent business organization would apply to its own industrial plant.

The surplus so applied would be for the welfare of the water consumer, in that it would make possible not only a reduction in rates, but also secure a greater safety and certainty in the production and distribution of water. At the same time, there would occur no discrimination in favor of the taxpaying citizen, as against the water-consuming citizen, a discrimination which has been condemned by courts and public utility commissions, where the latter have authority over municipally conducted utilities.

For the purpose of securing some information regarding the status of water fund diversion throughout the United States, a questionnaire was sent to over two hundred cities, of which number one hundred and six replied. Of this number, ninety-four reported themselves as self-supporting in every way, eight had annually recurring deficits and one was only self-supporting insofar as the works pays its operating expenditures. One hundred and four works reported on the question of separating funds. The funds of ninety works were kept separate in every way, but fourteen had their receipts paid into the municipality's general fund from which these were disbursed for any purpose deemed proper by the municipal authorities.

Ninety-nine cities reported on the question whether there had been any diversion of water works funds and twenty-nine answered, yes, and seventy, no. The questionnaire further showed that seventeen cities prohibited such diversion by local laws. There is, however, diversion in almost all of the cities studied on account of their not only accepting but demanding free service. Excluded from the cities questioned was Detroit, where the city charter provides that water funds may be used only for water works purposes. However, here also, the works must furnish free water to an amount approximating 15 per cent of its production.

John Chambers.[3] The Louisville Water Company is owned by the City of Louisville, the entire capital stock being held by the Commissioners of the Sinking Fund.

The property is under the management of a Board of Water Works, the members being appointed by the Mayor, subject to the approval of the Board of Aldermen, the Mayor himself being a member, ex-officio. Only one member of the Board of Water Works can be appointed each year. The term of office is four years. This is a wise provision, as in the event of a change in the politics of the city administration, only one member of the Board of Water Works can be changed each year. All officers of the Water Company are elected or appointed by the Board. The powers of the Board are broad and not subject to outside influence.

The Mayor of the city is elected in November and takes office during that month, for four years. An election for mayor was held in November, 1917, the successful candidate being inducted into office during that month.

In the year 1918 the Board of Water Works, at the suggestion of the Mayor, declared a dividend of fifteen per cent on the capital stock

[3] Chief Engineer and Superintendent, Louisville Water Company, Louisville, Ky.

of the Louisville Water Company payable to the Commissioners of the Sinking Fund. The purpose of this action was to avoid an increase of the tax rate and to make possible a reduction instead. The dividend, amounting to $191,265.00, was paid from earnings for the year 1917 which were $442,561.00. The same dividend was paid in the years 1919, 1920, 1921 and 1922. In the year 1923 the sum paid into the sinking fund was $173,157.24, the reduction being agreed to by the Mayor. Since that time the full fifteen per cent has been paid and there is every reason to believe that the practice will be continued. The total amount paid to the present time is $1,512,012.24. The bonded indebtedness of the Louisville Water Company is small, being $1,079,000.00, and, in addition to the dividend, the Water Company pays each year to the sinking fund a sum sufficient to provide for its own bonds.

It is probable that when the Mayor requested the first dividend he had in mind the loss of income to the sinking fund when liquor licenses should be discontinued, the advent of prohibition being apparently inevitable. In the year 1917 the sinking fund's income from license taxes was $509,007.00, of which $305,000.00 were obtained from liquor licenses. In 1918 the total income was $625,654.00 of which $419,000.00 were from liquor licenses. In 1919 the sinking fund received from license taxes $339,901.00 of which only $3,840.00 were from liquor licenses. From this time the receipts from license taxes were gradually built up until in the year 1925 they amounted to $694,939.00, as compared with $509,007.00 in 1917 and $339,901.00 in 1919. These figures are for license taxes only and do not include the dividends from the Water Company.

The net earnings of the Louisville Water Company from 1917 to 1925 were as follows:

1917	$442,561.00	1922	$500,037.00
1918	432,323.00	1923	555,451.00
1919	422,552.00	1924	607,425.00
1920	440,265.00	1925	687,580.00
1921	470,231.00		

It is certain that when the Board of Water Works made its decision to divert a portion of the earnings of the Water Company to assist the Commissioners of the Sinking Fund, the future needs of the Water Company had not been forecast. During the war very little construction work was done and the accumulation has had to be taken care of. Matters were made worse by a large increase in the population of the city, partly due to an increase in area of nearly fifty per cent in 1922, and partly to unprecedented growth due to other causes. The population of Louisville increased about five per cent during the decade between 1910 and 1920, when the Federal census showed 235,000. In December, 1925 a census taken under federal supervision fixed the population at 306,000, an increase of over thirty per cent.

The Louisville Water Company is now facing construction costs which will exceed $4,500,000.00 during the next five years, and that sum cannot be provided from earnings alone. Rates have been increased and it will be necessary to borrow money. The advance in rates has caused much dissatisfaction, although the increase is not heavy. If no dividend had ever been paid into the sinking fund the finances of the Water Company would be in a very healthy condition, it would not be necessary to borrow money and rates would merely have to be adjusted.

Although the idea of the dividend was a new one there was no open criticism until the rates were raised, effective January 1, 1926. At first the change was not well understood, but when the first bills were received there was a storm of protest. This was in the nature of open letters to the newspapers, letters to and personal calls upon the officers of the Water Company and one or two abortive mass meetings. The situation was not improved by adverse comment, editorial and otherwise, by a part of the daily press. The question was, why pay dividends to the city if the Water Company needed the money? Some business men of undeniable ability have held, from the first, that as the city had a large investment in the water property it was entitled to a fair return on its investment. The opposite view is that if the Water Company earns more money than is required for expansion the rate payers should benefit in reduced water bills.

It is not proposed to comment on the wisdom of the Board of Water Works in instituting the dividend. Opinion will vary with the point of view. It is, however, obvious that the question of diversion of the earnings of a municipally owned water works to other departments of the municipality should be considered with great caution. The practice may establish an embarrassing precedent.

J. E. Gibson:[4] We have tried to look at this thing from every angle but without regard to what approach we make, we always come back to the point that common honesty requires that all of the funds collected in payment of water and service rendered the consumer should be held inviolate and as a trust fund for the betterment of the service to the consumer.

The consumer is a rate payer without regard to whether he is a property holder or renter. The municipally owned plant is organized for the protection of the public and should be run without profit, for obviously it is an injustice to one portion of the public to make it pay a profit to other consumers or rate payers for a public service which should be rendered alike to all at equal cost. I know some argue that a renter or non-property holder pays no taxes and unless he is made to pay an indirect tax in higher price for the service rendered, he escapes. This is only to deceive themselves, and no one is worse deceived than the man who deceives himself. A non-property holder pays taxes just the same as the property holder. The only difference is that he pays them indirectly through rents, purchase of goods and other supplies used by himself and family while living in the community. Of course, some people will say that rented property does not pay, as the revenue is not sufficient to cover taxes, insurance, depreciation, and maintenance. In isolated cases this may be true, but it is a case where the investor has made a poor investment and his principal has shrunk due to conditions over which he or no one else had control. If we could all make investments with guarantee of no loss, there would be few bankruptcies in the world. The relation between the property holder in the city and the rate payer or consumer of a public utility, is the same as that of the banker and the borrower. The tax payer or property holder lends his credit only, and the rate payer or consumer becomes the borrower and should pay the interest, depreciation, maintenance, and operating costs for the service. When he has done this he has done all that he should, and any further payment is against the best thought of modern accounting. The day of bookkeeping as carried on by the crossroad mercantile house, where the members of the family helped themselves to whatever was required from the store without making an account therefor, is long past, and the same is true of the municipality. I maintain that all service given to the other departments of the city should be charged to and paid for by those departments, for service supplied without payment soon is abused and the benefits derived accepted without proper appreciation.

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[4] Manager and Engineer, Water Department, Charleston, S. C.

Fire hydrant service supplied to the community as a whole should be paid for by the community as a whole as it is of equal benefit to all. However, if given to the community by the Water Department without proper charge and payment, the property holder is receiving a service over and above the other rate payers, and the more expensive the property the greater the service rendered. This haphazard method of keeping municipal accounts reverts to the crossroad mercantile house, and I believe our courts and commissions are taking the proper step when they insist upon the funds of the utilities being kept inviolate. If the rates are too high, resulting in the accumulation of too large a surplus, then the rates should be reduced so as to give the rate payer the reduction direct.

The most recent case that I can recall is that of the Supreme Court of the State of Ohio enjoining the City of Cincinnati from increasing the rates of its water department, diverting the funds to fire and police departments and to schools. Cincinnati vs. Roettinger, 105 O.S., page 145 (Supreme Court of Ohio)).

Some years ago there was a very admirable paper presented before the New England Water Works Association by Mr. Burnham, giving a summary of statistics collected by him covering this subject. I have from time to time added to this and would be glad to furnish anyone who is interested with a copy.

George H. Fenkell:[5] A municipality should construct, operate and maintain a municipal water plant for furnishing a good and efficient service for the community, rather than to produce revenue to be used to finance other city activities.

In a decision of Uhler vs. The City of Olympia, vol. 87, p. 1, Washington State Report, the principles underlying the difference between a citizen tax payer and a citizen water consumer are discussed. The Supreme Court in this case, which was one affecting the debt limit of the city of Olympia, states that the charge for constructing, operating and maintaining the water works should be placed upon those who use water and not upon others; that the revenues to be received from the water plant are not monies of the city; they do not partake of the character of general funds; that the object of municipal ownership is to give the citizens the best possible service at the least possible price; that the citizen who is taxed to the extent of his use of the utility is entitled to all benefits; that when the plant is maintained, the interest paid, and a sinking fund is provided for the bonds, the tax payer—the water user—who is primarily burdened with meeting the maintenance, betterments, interest and cost of the system, is entitled to the benefits.

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[5] Superintendent and General Manager, Board of Water Commissioners, Detroit, Mich.

From the above dictum of the above noted State Supreme Court, it is evident that the surplus earnings of a municipal water works belong to the water user, and that the surplus must be expended for improving the works so that these may be more efficiently operated, for extending the works so that a greater number of citizens may become water users and, if there is no such room for improvements and extension, it must be applied to a reduction of rates.

Where water funds are separated from other accounts, there is much less danger of diverting them to purposes other than those of a water works. There is a public knowledge, when these funds are kept separate, of their existence, and there is less danger of having some municipal body misapply these funds to other municipal operations. On the other hand, where water works funds are not segregated, but are mingled with funds raised by general taxation, the danger is at all times present that the water works' share will be used for purposes foreign to the water utility.

In Detroit, the Water Department serves a number of cities and villages adjacent to Detroit, and in the majority of these, there are no segregated funds against which water expenditures are charged, or to which water revenue is credited. Municipalities operating in such way at Detroit are often found on the list of delinquents. Because of pressing obligations of various kinds, the water receipts are used for purposes other than those for which these receipts were collected.

THE VALUE OF WATER WASTE SURVEYS IN ADDITION TO THE LOCATION OF LEAKS[1]

EDWARD S. COLE:[2] Much has been said in regard to the desirability of reducing the waste of water in distribution systems by locating leaks in the mains, services, etc., but I believe that half the value of a water waste survey lies in certain other items of information which can be secured only from such a study. I shall try to outline some of these incidental points of interest in support of my claim.

Checking maps and records. The average water works plant in a small town or city has been in operation for many years and in the early days methods of keeping records of what went into the ground were very crude. As a rule, these records were in the head of the superintendent who had possibly been employed on the construction of the plant, and who guarded them jealously because of the feeling that his value to the city or company depended on this knowledge.

In the course of a water waste survey from 75 to 100 per cent of the valves are operated and in this manner their location can be checked on the existing maps, as well as the size and location of the mains.

Condition of valve system. In addition to checking the location of the valves, their condition can also be noted and repairs made wherever necessary. In many cases the valves have not been operated for so long a period that many of them will not hold tight and some cannot be operated at all. In my opinion a valve that will not hold tight in an emergency is money wasted. It is, of course, of the utmost importance to keep the valve system at the highest degree of efficiency. The water waste survey emphasizes the need of periodical inspection and has been the means in many cases of inaugurating a definite program of inspection and repairs.

Closed valves. Another important feature of the survey is to discover if valves supposed to be open are open, and whether or not the valves on service boundaries supposed to be closed are closed.

Frequently we find valves on main feeders in the distribution system closed with a resultant loss of pressure, in many cases creating a situation which would severely cripple the system in case of fire.

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[1] Discussion before the Buffalo Convention, June 7, 1926.

[2] President, The Pitometer Company, New York, N. Y.

We recently completed a survey in a city in New York State with about 50,000 population, in the course of which we found a gate closed on a 20-inch main, which was one of the principal supply lines to the city. This condition was forcing a flow of water of over 2¼ million gallons a day, or approximately 6½ feet per second through a 10-inch main. Later on we found a valve closed on another main feeder, and when these two valves were opened the pressure in the center of the city was increased by 20 pounds. The estimated cost of the cast iron main lying idle while these two gates were closed was $100,000.00.

In another city of New York State the system is divided into a high and low service, the low service being supplied by gravity and the supply of the high service pumped and filtered. The valves were supposed to be closed between these two services, but a water waste survey revealed the fact that a 6-inch boundary valve was open and about 400,000 gallons a day of costly pumped and filtered water was being discharged from the high into the low service. This amount was just as definite a loss to the city as if it had been escaping into a sewer from an underground leak.

Distribution of supply. The usual method of conducting a water waste survey is first to divide the distribution system into several districts and measuring the flow of water into each district for a period of not less than twenty-four hours. The information thus obtained is of the greatest value. It frequently discloses inadequacies in the gridiron system which can be remedied by laying reinforcing mains. These deficiencies are usually made evident by abnormal drops in pressures while the various districts are being isolated.

Engineers are very often employed by water companies and municipalities to redesign the distribution system to meet present needs and future requirements. The information secured from district measurements is of great value in a study of this kind, as it indicates the points of maximum consumption and also shows the maximum demand in each one of the various districts into which the city has been divided.

Trunk mains. In studying the waste conditions in larger systems it is usually necessary to test the trunk mains separately from the gridiron system by making simultaneous measurements at various points, shutting off all laterals between these points. These measurements not only show the existence of underground leaks in the mains, but indicate those mains that are being overtaxed with a resultant loss of pressure in the areas they are supplying. They sometimes show that a large main supposed to be the principal supply to a certain section is in reality doing no work at all. These conditions frequently can be remedied by laying short cross connections or by valve operation, and if this is not possible the needed reinforcements can be designed to the best advantage.

C. C. Behney: A number of engineers and water works superintendents have realized the possibilities for considerable savings and direct financial benefits and other advantages to be derived from water waste surveys. Few if any have been disappointed with the results obtained, and often the results have been beyond all expectations.

The writer has been in charge of a number of waste water surveys and judging from the results of these, it can be said that the annual savings as a result of the surveys were more than the costs of same.

Waste water surveys are not new, and much has been said and written on this subject, but anything which offers such benefits and such handsome returns on the investment bears repetition or elaboration.

Briefly summarized, a waste water survey properly conducted will accomplish the following:

1. Locate leaks with surprising accuracy
2. Locate wanton waste of water
3. Check large meters in place
4. Disclose unauthorized use of water
5. Check the pump slip
6. Give valuable engineering data
7. Check the condition of valves
8. Restore valve boxes to the street level
9. Check the condition of fire hydrants
10. Determine the distribution of flow to districts
11. Increase the pressure in the distribution system

A waste water survey:

Conserves the water supply
Postpones plant expansion
Saves interest on large invesements

Decreases waste
Increases distribution efficiency
Increases fire protection
Increases revenue

It is difficult to determine the value in dollars and cents of each of the several benefits and advantages just stated, and no doubt for this reason we usually think of the value of the waste and leakage which is recovered by a waste water survey. It is this factor more than any of the other benefits, which usually prompts action and leads to the making of a waste water survey. Likewise, it is for this reason no doubt that some are content to equip themselves with sound intensifiers and set out to search for leaks. Undoubtedly some leaks can be located by this procedure, but will you realize the most value for your efforts? Will you locate as much leakage by this procedure as by a comprehensive waste water survey, which furthermore gives many additional benefits? Sound intensifiers play a very useful function in locating leaks, but the value of first having an indication of an existing leak should not be lost sight of. This can readily be determined by measuring the flows to small subdivisions by means of a pitot tube. It enables one to know how much and where the water is going.

The amount of leakage that may be recovered in a system depends upon conditions and the nature of existing leaks and waste. It is not to be expected that all leakage and waste will be recovered. A perfect system would be able to account for 100 per cent of the water pumped or supplied. Some systems account for 90 per cent or better. That is, the leakage and waste are less than 10 per cent. If this can be accomplished in some systems, it is reasonable to expect that like results can be obtained in similar systems.

After a waste water survey the Syracuse Suburban Water Company was able to account for about 95 per cent of the supply.

After a survey at Lexington, Ky., they could account for about 90 per cent of the water pumped. The leakage recovered amounted to 17½ per cent of the water pumped.

At Hagerstown, Md., a waste water survey brought the per capita consumption down to 38 gallons per day exclusive of the industrial consumption. Accordingly 38 gallons per day per capita represented the domestic consumption and included whatever leakage and waste that may have remained unrecovered. The leakage recovered amounted to about 16 per cent of the total supply. The yearly saving in electric power at the pumping station exceeded the cost of the survey. This was a gravity system and the only pumpage was that of a booster pump.

In the City of Syracuse, N. Y., a survey recovered 4 000,000 gallons per day, or about 15 per cent of the total supply.

D. A. Heffernan:[3] I am a great believer in the water waste survey. In 1890, before this work was done as commonly as it is now, we had our own method of determining the location of leaks in our system in Milton, Mass. This method, while considered old-fashioned, was entirely practical and still is today. The method we used was by means of test pits. By this I mean that a tap was made either side of a valve in the main line of a distribution system. These pits are conveniently located in various parts of the system so that, by operation of gates, the system may be divided into a number of parts. When in actual use the taps are connected together through a 2-inch meter forming a by-pass around the main valve, which is closed.

Only six months ago we had a bad leak which increased our consumption about 30 per cent. We discovered the presence of the leak through reading of the master meter. Upon discovering that there was a leak in the system we divided the town into four sections, on paper, and starting out at midnight we cut off one section after the other until we discovered that the leak was in the last section to be tested. After locating the leak roughly we moved our testing apparatus to a pit in the section in which the leak was and from this location we were able to confine it to an intersection of four streets. The geophone brought us to within 6 inches of the actual break which was in a 6-inch main within a few inches of a sewer manhole.

The main at this point had rested on a rock and I suppose that the heavy trucking which the street carried had caused the pipe to settle, breaking the pipe clean. The break, occurring so close to the manhole accounted for the fact that no sign of the leak showed on the surface of the street. As I have said, the road at this point carries a considerable amount of traffic at all hours of the night and as it did not appear feasible to divert the traffic, we used the geophone by getting down on our knees and throwing a blanket over us covering ourselves and the geophone entirely, tending to exclude foreign noises. After making the simple repair our consumption went back to normal and, by the way, has remained there since.

We are 100 per cent metered and have been since 1890 and we are able to account for about 85 per cent of our water. We do not allow for slippage of meters in computing our accounted for water and I would like to take the opportunity to ask Mr. Behney if slippage was allowed for in his computation of accounted for water.

C. C. Behney: Yes, it was allowed because the water was measured by a meter.

D. D. Heffernan:[3] The usual practice, I think, will allow two or three per cent variation for the slippage of meters.

C. C. Behney: I mean there was no allowance made, but the meter actually measured actual pumpage.

D. D. Heffernan: I have mentioned these facts because I am proud of my system. We have 60 odd miles of pipe in a town of 13,000 people. In order to keep the consumption down to 600,000 gallons per day and per capita consumption at 45 to 47 gallons per day, the system has to be pretty tight and the reason for having such good results in our case is due to the fact that we do our own work, lay our mains and services from main to meter. I have given thirty-six years to my little system and I hope my pride in it may be pardoned.

Wm. A. McCaffrey:[4] A leak of 125,000 gallons a day is a very small one. Here in 1918 we thought we might have a survey. There was no leak showing above ground whatever, and we knew that we had no leak underground. The former superintendent had made a recommendation to put in another eight million gallon pump, but finally we had it surveyed and we found one twenty-inch main, that had a leak of 150,000 gallons a day. We found in a 6-inch main going into a boiler shop, a leakage of 345,000 gallons, in another main a leakage of 70,000 gallons a day and in another main 500,000 gallons of water being used and not being paid for; that was in a starch factory. The owner of the starch factory years ago owned the water works.

[3] Superintendent, Water Department, Fulton, Mass.

[4] Superintendent, Water Works, Oswego, N. Y.

Chairman Gensheimer: Was that a leak?

Wm. A. McCaffrey:[4] No, that was not a leak, that was use, but the present owner knew nothing about it, so he said. When we got through with those leaks, we decided that we did not require a new pump, but I think now that within the next year or so we will have another survey in order to find the small leaks.

Mr. Pierce: This applies to us small fellows as well as you big fellows, and it does produce some surprising results. For instance, one night we were trying to isolate a section to start work. We attempted to close one valve, but we could not find the stem to put the key on, so we let that go. The next morning we asked the foreman who had been on the job some twenty odd years, what he knew about it. He did not know much about that valve except that there was one there. He remembered some fifteen years previously that they had tried to turn the valve and had broken the stem. They had taken the gate and stem out, but did not have another to put back, so they put a wooden plug in and forgot all about it. We tried to convince the superintendent that leaks were below the surface and did not appear on the surface. We were able to find a leak going into a sewer. A nearby house had complained about a noise on the pipe, but when the leak was repaired, the noise stopped. In another case we found that at certain hours in the day there was a reversal of flow. Those of you who are interested in checking your pumps may refer to the December, 1923, issue of Engineering and Contracting, where there appeared a short article describing the method to be followed in pump slippage.

Mr. Patten: What is the usual practice in figuring per capita consumption?

Wm. A. McCaffrey:[4] A great many take the total consumption on the total pumpage and divide by the population.

Mr. Patten: The objection to that is that some towns have a very large industrial sale of water. Other plants have almost no sale to the large industries. Consequently you have not a reliable guide, I think, in figuring per capita consumption, where you are not stating that you previously deducted the sale to industrial consumers. This ought always to be deducted. The water that is sold to factories by meter should be taken from the total pumpage and then with the estimated population you will get the per capita consumption.

Mr. Pierce: In the back part of the Manual of Water Works Practice there is a form suggested to be filled out for different water works statistics, and in that it describes how to figure the per capita. I believe that includes everything. The estimated number of people served, not the estimated population of the city, is used.

E. S. Cole:[2] In The Journal for March, 1915, will be found the report of a committee on Water Consumption of which the speaker was chairman. This report contains a chart showing the gross per capita consumption of 133 cities. Two shaded areas represent the metered domestic use and the metered non-domestic use respectively. The importance of segregating industrial from domestic use is thus clearly brought out and it would seem that the per capita rate, *after excluding industrial consumption*, is the only safe criterion of use or waste by which we may compare one city with another.

Mr. McDowell: In connection with the computation of consumption per capita, I can recall one case, that of a town using about 5 million gallons of water for domestic use, where the industrial use in one plant ran up to 72,000,000 gallons a day. That would be very misleading if they did not exclude the use for industrial purposes. In connection with the water waste survey, some little experience I had in detecting a reversal of flow might be interesting. We had one block in the city that was continually complaining about red water. In that street one of the earlier mains was laid. I went down there for the purpose of really determining the pipe coefficient preparatory to cleaning it, and in installing the pitometer I found a reversal of flow before I got all my valves shut down. That probably was the reason of these complaints. I suggested that we deadhead one end of the line, which we did, and we had no further complaints from that source for about two years, when we replaced the line with cement-lined pipe. There was another case where I was trying to confine the water to a certain district, in order to measure the flow, and I got it down to about fifty thousand gallons in one block. It was near the edge of the harbor, where it was pretty difficult to locate a leak exactly, but before completing the investigation, we did find a leak in the main that was discharging into a sewer. It revealed itself.

L. S. Spire:[5] In the city of Buffalo, for the eleven months of the present fiscal year ending May 31, this year, our increase in consumption amounts to about two hundred million gallons. Our increase in industrial use is increased about four hundred and fifty million gallons. Now we are going to show an increase in pumping, but still we show an increase in industrial use. I was amused to hear Mr. McCaffrey speak about the pitometer survey in Oswego. The Pitometer Company made a survey here, starting July 1, 1917, and spent two years here. I would like to mention two instances of leaks found. One was in the rock section of the city, near the quarries. The pitometer showed in this sub-division, in between two valves in one block—and, by the way, there are no connections off of this sixteen inch main—a flow of 250,000 gallons. On investigation we found a beautiful drinking place built in this quarry with a nice, shiny dipper. The watchman that night said. "We have a nice spring here; for several years it has been going so fast that we have to have an electric pump to pump it out." Again, I discovered a break in a sixteen inch main. In another instance, in a park we have a quarry and I found water flowing in there. I shut the main off and the water stopped. A man had been coming down there with a huge bottle for this spring water and he was keeping it a secret. Afterwards he had to go elsewhere for his spring water.

Buffalo is about 15 per cent metered, so you can see the enormous house waste we have. The industrial use in the city is about 33 per cent of our total pumpage. Last year inspectors were sent throughout the district, and we had it measured for the entire year, or rather about ten months of the year. They reported approximately 27,000 fixture leaks and about 2000 service leaks.

H. P. Bohmann:[6] Per capita consumption does not mean anything. Buffalo supplies a population of 550,000. The year I made a comparison with the city of Milwaukee, you were serving the same population we did. I found that you were using as much water thirty years ago as we are using at the present time, so that proves

[5] Chief Pitometer Operator, Bureau of Water, Buffalo, N. Y.

[6] Superintendent, Water Works, Milwaukee, Wis.

that per capita does not mean anything. Previous to 1912, no effort was made to account for the water that we were pumping, but since 1912 an effort was made to secure this information each year.

HENRY T. GIDLEY:[7] You might be interested in a leak we found in our town. The owner of a garage on Main Street called me up one day and told me that he had been having trouble with water in his boiler pit. It would rise up and threaten to put out his fire. He said that it had been running for three weeks, and it got so bad that he had to install a gasoline pump to take care of it, and the water was so clear that he thought it might come from our system. We went over to make an investigation and told the man to shut off the service on that line. There were two boxes outside, and when I went out to see, he had shut off the wrong box, or started to, and I told him that was an abandoned service. "Well," he said, "that service was turned on full." When that was shut off the water ceased immediately. I made some inquiries about the garage, and it seems that three weeks previously, on a Sunday afternoon, some one had broken off the gas pipe left inside the door to the garage. They sent for the gas company and the superintendent of the pipe department came over. Although our box was marked water very plainly, right in front of the door, he put his stock wrench on it and turned on the water. He did not seem to stop the gas, so he finally plugged the pipe inside and went away without saying anything. I thought that probably the stream from this old service would run about the size of a half inch stream, so I put a meter on our meter tester and ran it for a little while to see about how much it would run in three weeks, and sent a bill to the gas company. The treasurer of the gas company, whom I have known for quite a number of years, was quite put out about it, and wanted me to step in and see him about it. In the meantime his superintendent had been over to see me and wanted to know about it. He said he turned it on but it was an accident. Finally I saw Mr. Price and talked it over with him. He finally settled the bill and I do not think they will turn on a water pipe again.

ELON P. STEWART:[8] In Syracuse we have been carrying on water waste surveys with our own forces for over two years. We have received all the benefits mentioned by Mr. Gidley and Mr. Cole in

[7] Superintendent, Fairhaven Water Company, Fairhaven, Mass.

[8] Engineer, Water Waste Survey, Bureau of Water, Syracuse, N. Y.

making such surveys. Our water does not have to be pumped, it runs by gravity, but there is one thing that means dollars and cents that I want to call to your attention. There has not been much said on this tonight, and that is on the question of checking large meters. I found one meter, one of the largest in the city, about 50 per cent slow, which was quite an item in itself. It is not uncommon for me to find them 10 or 20 per cent slow, or any ordinary amount of that kind. A small water district near Syracuse engaged me a short time ago to find out why they had so much unaccounted for water. They were determined that somebody was stealing it. On checking it up, I found that their master meter was about 40 per cent fast, and on taking it apart, it was a turbine type, we found it all clogged up with moss and stones. It was cleaned out and the trouble was over and they were satisfied.

A Member: I would like to ask Mr. Stewart if they furnished the water for that master meter?

Elon P. Stewart[8]: No, they turbined it from a neighboring village.

Mr. Patten: For the last four or five years we have been buying nearly all our meters from one company. We kept getting so many complaints about the large bills, that I took one of these meters out and tested it. Nearly every one of them that I tested was 5 per cent fast. They are all tested when they reach our shop, and they are approximately accurate, say within 1 per cent, but after they have been in service for six months, they get 5 per cent fast. I cannot account for it. I do not see how a meter can get fast.

A Member: What is your pressure?

Mr. Patten: Eighty-five pounds. I can see how a meter can get slow, but not how it can get fast.

A Member: Any corrosion?

Mr. Patten: No corrosion whatever. The explanation of the meter company's representative is that the meters probably were not sensitive enough when they left the factory and after they had been in service a little while, they became more sensitive.

MR. McDOWELL: I would like to ask Mr. Stewart whether they were all turbine meters he found fast?

E. P. STEWART:[8] The one I found fast was a compound meter; the slow one was a turbine meter. I found almost every type slow, but the fast one was a turbine type. I have asked our chief meter repairman what had been his thirty years' experience in repairing meters and finding them fast. He said that in the turbine type it was quite common to find them fast from clogging up with moss and that he had found meters fast of the disc type when there was a little coating of oil or grease on the disc. How often that occurs, I do not know, but he said that he had actually tested them and found that condition.

MR. TAYLOR, of New Brunswick: We sometimes find a disc meter fast. Our water carries a little vegetable matter in suspension and that sometimes forms on the inside of the measuring chamber, which of course reduces the size of it. They will run as high as 4 or 5 per cent fast, but that is after a considerable time, when they have had time to accumulate a lining on the inside. Sometimes I think the difference in the pressure where they are tested and where they are put in service makes a difference too. For instance, we test at 85 pounds pressure, and if a meter is put in under 20 pounds pressure, you might not get the same results.

UNDERGROUND WATERS AND PUMPING THEREFROM[1]

By George W. Trauger[2]

My residence in California for almost eighteen years, and particularly in Tulare County, where there are in excess of twenty thousand acres planted to citrus groves, irrigated exclusively from underground waters with which I am familiar, and my connection with the Lindsay Strathmore Irrigation District since its organization on November 9, 1915, first as field engineer and for the past eight years as Superintendent and Manager, has given me some knowledge of the subject of underground waters. The Lindsay Strathmore Irrigation District has been an object of interest to engineers, lawyers, and water users generally, for the past ten years, by reason of protracted litigation involving its water rights. I wish to apologize to the learned members of the bar who may be present, for placing engineers ahead of them, but I believe in this particular instance we engineers started something, and we now pray that the lawyers will finish it. Believing that my connection with the Lindsay District is the primary reason for my selection to discuss this subject, and also because this District is vitally concerned in underground waters and pumping therefrom, I am going to review the history of it.

The Lindsay Strathmore Irrigation District was organized on November 9, 1915, under the "Irrigation District Act of the State of California." It extends from the Southern Pacific Railroad on the west, eastward to the westerly slope of the Sierra Nevada Mountains, and from a point three miles north of the Town of Lindsay, Southward to Strathmore. Its boundaries are irregular. Its gross area is slightly over 15,000 acres. The district lies wholly within Tulare County. Prior to the year 1900 the land now within the district was used either for dry farming or allowed to be fallow. By 1903, five hundred acres of the area had been planted to orange trees, many of which were in bearing. These plantings showed that valuable citrus crops could be produced by irrigation with water pumped from underground sources. As a consequence, the development from 1903 to about 1914 or 1915 was rapid, and by the end of 1914, over 7000 acres had been planted to citrus crops. Of these about 6000 acres were in full bearing. Practically all of the San Joaquin Valley is semi-arid, in the sense that irrigation is necessary to profitable production and this is particularly true of that portion of the Valley now known as the Lindsay District. The increased draft on the water sources to serve this additional planting, so lowered the water table that the supply showed evidences of depletion as early as 1912 or 1913, and by 1915 the water supply had given out entirely in some areas, and in others it had become so salty that its use for irrigation purposes became injurious, if not absolutely destructive of the crops and trees to which it was applied.

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[1] Presented before the California Section meeting, October 29, 1926.

[2] Superintendent, Lindsay-Strathmore Irrigation District, Lindsay, Calif.

It therefore became necessary for the land owners to acquire other water sources from which a sufficient supply could be obtained. Otherwise the area about Lindsay would revert to desert conditions of earlier days. About ten miles north of the Town of Lindsay there was found a tract of land lying on both sides of the Kaweah River, known as the Rancho de Kaweah, and consisting of course sand and gravel filled to the surface with water. Opinions of competent engineers were obtained to the effect that sufficient water to supply the needs of the citrus groves in and about Lindsay could be obtained by pumping from this underground basin, and relying thereon, the Lindsay Strathmore Irrigation District was organized in 1915; the Rancho de Kaweah was purchased; and thereafter thirty-nine wells, spaced at one-eighth of a mile apart, were bored, and are now, and have been since the year 1918, pumped and the water obtained thereby transported to the lands within the Lindsay District.

About 12,000 acres of citrus orchards to the west of the Southern Pacific Railroad remained out of the district, feeling that their supply was ample and would hold out with the discontinuance of pumping on the East. About 500 acres located inside the district boundaries also decided to take a chance on their wells in preference to coming in. Practically all of these last mentioned lands exhausted their supply in a few years and have since been taken into the district. This was done by buying unimproved lands within the district and thereafter excluding them and substituting the improved lands in their place. This entire project was approved by the State Engineer, and by several very well known engineering firms; bonds of the district were approved by the State Bond Commission, and were sold at or very near par. The outstanding bonds consist of two issues: the first issue in the amount of $1,400,000 sold at a premium; and the second issue of $250,000 sold at slightly below par.

The history of our water conditions is similar to that of many other parts of California. The area west of the Southern Pacific Railroad, before mentioned, is now finding that it also has a water problem. Its supply is greatly depleted; many wells have become salty; the water table has been lowered beyond an economic lift. This is due to several causes. First, many sections have developed by the use of underground waters, without any study of the amount available and the possibility of replenishment. It should be the purpose of men who develop projects of this character to prevent over-drafts on underground basins. This is done by our state where districts are formed, but I have in mind cases where an individual will drill a well, get water and profitably raise crops; then another comes in, and does likewise. Some real estate company buys large tracts, sub-divides the same and sells to innocent purchasers on the strength of what this or that man has done. In the course of a few years there is no adequate supply and failure for many is the result. I favor either a state or even a county control of drilling wells. This may be impossible. There certainly should, however, be some control of men drilling wells in order to protect the public. Enough money has no doubt been wasted by poor well drilling, poor equipment and unscientific methods, to build many good storage reservoirs. Many of these men do not even know how to keep a log of a well. I have known many cases where a rancher has drilled a well, usually for convenience, near his property line, sufficient for his needs; then his neighbor drills just across the line; then they play hide-and-seek with each other until one "goes broke." I know whereof I speak. I have lived on an orange grove, and still do, and have seen this very thing happen many times. The State keeps tab on the drilling of oil wells; why not on water wells?

Secondly, there must be a greater effort made to conserve our water in times of heavy run-off, both by building reservoirs, and when these are full by spreading as much as possible to build up the underground storage. This means a study of the underground basins and means of replenishment. The great advantage of underground storage is not fully appreciated. In our own case, the past three years have amply demonstrated that where it is possible this is the best storage. We were able to meet our needs in a fairly satisfactory manner, when almost any other plan would have left us "high and dry." In many cases the underground storage basin is filled by fall and winter flows that otherwise would be lost, leaving available for spring and early summer irrigation a greater amount of water. For this reason a better study should be made and a systematic way worked out for the filling of these basins.

A condition that is true of the Kaweah River is also true of many other streams of California. This river, with a water-shed of about 600 square miles, rises at the top of the westerly slope of the Sierra Nevada Mountains at an elevation of 10,000 to 12,000 feet. This stream with its tributaries has an annual run-off of about 450,000 acre feet. From 1915-1916 to 1925-1926 the average run-off was 295,000 acre feet. From 1906-1907 to 1915-1916 it was 458,700. This is 1,550,000 acre feet less than normal for the past ten years. These figures, which do not take into consideration the big year of 1905-1906, account in a large measure for the present acute condition.

An underground reservoir will store and hold water, especially where there are often early fall rains which bring up the flow of the rivers, and heavy floods during the winter and spring. These fall and winter flows will replenish the basin, in most cases, before the water is needed in the regular irrigation period. A well on the Rancho de Kaweah is at an elevation of 411 feet, about 10 feet higher than flood level of the river, and never according to our records subject to overflow. It is in an area where about 14,000 acre feet has been pumped out each year for the past eight years. It gives a good idea of how water can be stored, used and replenished. On April 3, 1918, before any pumping had been done in this area, there being no wells closer than two miles or more, the water in this well was 11.5 feet from the surface. On April 29, 1926, the water was only 14.9 feet from the surface. It must be remembered that in this section of the San Joaquin Valley, the years 1924, 1925 and 1926 were very dry, but with all this pumping and dry years, we only have a loss in ground water elevation of 3.4 feet.

On the same well the draw-downs over a period of a year were taken each month during 1921, a normal year in rainfall, snowfall and run-off. On April 4, 1921, the depth to ground water was 12.3 feet; by May 2, 1921 it was 16.8 feet; on June 1 it had come back to 14.4 feet, due to flood waters from melting snow, the river over-flowing its banks. By November 2 it had reached its lowest point, 23.5 feet, and by April 7, 1922, it was back to 13.7 feet, and on May 4, 1922, it was 12.6 feet, or only 0.3 of a foot lower than the previous year. Many of these areas that are pumped have been greatly benefited by holding the ground waters below the root area of the growing crops and in many districts pumping is absolutely necessary to keep the ground from becoming water logged.

At this point I wish to tell of the owners of 60 acres of orange orchard, who came in one day to find out if we would install a meter for them. They were part owners in a large well; the water was not measured and they felt they were not getting sufficient for their needs, or in fact their share of the water. I found out, before getting through with them, that at the time they were planning to buy drainage pipe to draw off water, and that even the water they were getting was just twice what they needed for an orange grove, located as theirs was on very heavy soil. I had to show them some mighty fine groves, with a metered system, using the needed amount, to convince them. Which only goes to prove, as I believe, that in many cases ground waters are being used far beyond reasonable requirements, and in many cases to the actual injury of crops.

A short review of the history of the litigation in which the Lindsay Strathmore Irrigation District is involved may be of interest. Furthermore, the effect of its final outcome upon our District may be of vital importance to other districts and municipalities. The original complaint was filed on July 15, 1916. Included among the plaintiffs were one irrigation district, 17 mutual water companies, and 56 individuals. The purpose of the action was to enjoin the Lindsay Strathmore Irrigation District from pumping water on the Rancho de Kaweah, and conveying it to lands within its boundaries for irrigation and domestic use. Briefly stated, the complaint alleged: That the underground water body in the Rancho de Kaweah is a part of the Kaweah River; that the defendant has no right to take any of the surface water of the river; nor any right to reduce the flow of the Kaweah River as the same passes over the Rancho, by lowering this underground body of water which, it was alleged, supported the surface flow. The stand of the defendant, briefly, was: That there was and is a surplus of water over and above the reasonable needs of all the plaintiffs, allowing for ditch seepage and the thorough irrigation of approximately 100,000 acres shown to have been irrigated. All of the principles of law applicable to water and the use thereof were involved in this case. The plaintiffs included in their number riparian owners, overlying land owners and appropriators from natural streams. The right of ditch owners to water lost by seepage from the ditches; the right of overlying land owners to underground waters built up by natural streams; the rights of riparian owners as affected by the "Water Commission Act of 1913," were argued and considered. I should know considerable on this subject after ten years of litigation, and the study of a collection of field data that treats on it from every angle. As a result, only one thought is uppermost in my mind: it is that underground water is and will be for many years to come an important factor in making possible the irrigation of large areas in California.

The complaint was filed July, 1916, and the trial began October, 1917, before Judge Wallace in the Superior Court of Tulare County. It closed after sixteen days of argument, in May, 1919. The Court gave its opinion in favor of the plaintiffs in July, 1919. The Supreme Court of the State was asked for a Writ of Prohibition, to prevent the entry of a judgment in accordance with the opinion, on grounds that the Judge was an interested party, he having a small lot underlaid with the same body of water that the dispute was about. The writ was granted, and all proceedings to that date were declared invalid. Judge Jones of Nevada was called in, and he made an order requesting the Governor to appoint a Judge outside the County to hear the case. Judge Kinsell of Oakland was appointed, was taken ill after hearing a few motions, and resigned. Then the Hon. Peter J. Shields of Sacramento was appointed, but on account of pressing business in his court, could not serve. Then Judge William M. Finch was appointed and accepted. The trial of the case proceeded before him for about four weeks, when he was offered a seat on the District Court of Appeals, Third Appellate District. This he accepted and withdrew from the case. During Judge Finch's stay on the bench, he repeatedly urged a compromise and even said the means were not lacking whereby this could be done. Judge Seawell of Oakland was then appointed and accepted, but after a brief stay found that his wife had relatives that had land in our district, and retired. Judge Albert Lee Stephens of Los Angeles was next appointed and accepted the task of trying the case. After almost two years delay, the case opened November, 1921, with Judge Stephens presiding. The trial closed July 31, 1923. Final arguments were made in Los Angeles in December, 1923. Judge Stephens issued a memorandum opinion in May, 1924. Findings of fact and conclusions of law were filed in May, 1925, ordering the issuance of a perpetual injunction against the Lindsay Strathmore Irrigation District. In April, 1926 the judgment was filed, and concurrently therewith an order suspending the operation of the injunction, on terms, pending an appeal to the Supreme Court which the Lindsay District announced it would take. At the time the findings were filed in May, 1925, the attorneys for the district made a motion for an order suspending the injunction pending the appeal. Judge Stephens made an informal announcement that he would grant the motion. The plaintiffs then asked the Supreme Court for a Writ of Prohibition to prevent the entry of such order. This matter was argued before the Supreme Court En Bank at Los Angeles. That court three months later denied the writ.

The case is now in the Supreme Court on appeal. The record on appeal consists of 25,000 pages of transcript, over 700 exhibits and the judgment roll, which comprises 900 printed pages. The cost has been, including both sides, close to a million dollars. There has been some criticism of the length of this trial, but I wish to say to this convention, that our people are very grateful that we have been able to hold the water during this period. We have had an opportunity to strengthen our position during the past two years, by the acquisition of water stock in mutual water companies and corporations diverting water from the Kaweah River. This water stock represents an amount of water in acre feet, 50 per cent greater than any amount pumped in any one year by our District, and we are now devising ways and means of using this water, if our appeal to the Supreme Court is not successful.

The Lindsay District has one of the most modern irrigating systems which is based on a high duty of water. Thirty-nine pumping plants are located on the Rancho de Kaweah; about 20 miles of redwood pipe, 14 to 48 inches in diameter, lead from the Rancho to a low line cemented canal, 6 miles long; this canal conveys the water to the main pumping station, three miles north of Lindsay. The total lift at the Rancho is about 120 feet to the main pumping station; there it is boosted 162 feet to a gunite bench flume 6 miles in length. From this flume the water is taken out and distributed over the district by means of 100 miles of riveted steel pipe, varying in diameter from 4 to 36 inches, and is delivered to the consumers under pressures varying from 0 to 75 pounds. The same supply is used for both domestic and irrigation purposes. At the end of the bench flume, two steel lines lead off, one 30 and another 36 inches in diameter. The first 4 miles in length supply a second small booster station where another lift of 160 feet is made to serve 2000 acres on a higher elevation. At this last lift the water is placed in a small cement canal 3 miles long and is distributed therefrom by steel lines. The system if 100 per cent metered, with loss from all sources of about 4 per cent. This includes the loss by metering as a whole at the source and distributing in small amounts. Our people like the meter system, and I am a firm believer that, where individuals own their own plants, the water should be metered, so that they can tell the amount used and have some idea that the application of water is near the amount needed for the crops being raised. The irrigation rate is $10.00 per acre foot and the domestic rate $20.00 per acre foot. This money is used on operation only, while bond interest and general funds are paid from direct taxes on all lands, the rate being the same on improved and unimproved lands. The average cost of water per acre which includes everything, including litigation, is about $26.00 per acre.

The balancing feature is taken care of by a small reservoir holding 20 acre feet, located about one quarter mile beyond the last pumping station, and 25 feet higher. The pumps are connected with the line going to the reservoir, and the surplus, if any, goes by. If a shortage exists the same line carries the water back.

The irrigation season normally is about 210 days, depending greatly on the rainfall, and water use is based on a high duty and economic handling. The duty is about 1.6 acre feet per year. A certain amount is allowed per acre each thirty day period, and the consumer is usually permitted to take the same in heads as needed. Very few services take as high as 35 inch heads, the average being about 15 inches. Our connected electric load is 3750 h.p., yearly use over 10,000,000 k.w.h., and the rate is about 0.8 of a cent per k.w.h. and voltage on all motors 2200.

The experience of the last ten years with the affairs of the Lindsay Strathmore District has caused me to form the opinion that no more dependable supply of water for irrigation purposes can be obtained than that from underground basins. Nature has created many such natural reservoirs in California, of which that tapped by the Lindsay District is probably the best. The rains of the fall and winter, and the snow flow of the spring and early summer, are rapidly absorbed and as rapidly extracted by the pumps. The rate of underground lateral percolation is so slow—about 6 feet a day—that little water escapes. In a climate where evaporation from water surfaces is so great, from 5 to 7 feet per annum, the storing of water underground completely salvages this loss, provided the water table in the sands and gravels is not less than four feet below the surface. In my opinion the most economical method of conserving water is to take advantage of these natural storage basins, and, by causing the surface flow of the streams to pass over wider areas, to increase the absorption thereby. No more economical and permanent source of supply can be obtained.

WATER SHORTAGE IN INDIANA[1]

By Lewis S. Finch[2]

A discussion of water shortage in Indiana is of particular interest at this time, since the dry weather during the past spring and summer caused shortages at places where this difficulty had never been experienced before.

The public water supplies of Indiana are obtained from shallow and deep driven wells, dug wells, streams, natural and impounded lakes, and springs. As would be expected the supply of water from impounded surface sources is subject to the greatest seasonal fluctuation with regard to quantity, although the ground water supplies are also subject to serious shortages, due principally to a lowering of the ground water level.

The semi-public and private water supplies are drawn mostly from dug and shallow driven wells and cisterns. Usually these private and semi-public supplies are the first to suffer a water shortage, but, since in each individual case a comparatively small number of people is involved, I shall not touch upon this phase of water shortage except in one case. In that instance, the shortage of water on one man's farm seriously involved a public water supply and endangered the health of about 5000 people. This man raised hogs and due to the dry season, the pond from which the hogs drank, and in which they wallowed, dried up. It then occurred to this farmer that a water main ran across his farm, and that at one time a tap had been made on this main. What could be simpler than to find this tap and permit enough water to run out of the main to provide a pond for the hogs. Of course, anything taken from a public utility is not stealing, so he at once acted. On the very top of a hill he found the tap buried, and very conveniently for him, a valve had been left on the pipe. He cracked this valve and then covered up the connection, and went his way. Soon, on the top of this hill, a pond appeared, and the hogs found it a most wonderful place.

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[1] Presented before the Indiana Section meeting, March 26, 1926.

[2] Director, Water and Sewage Department, State Board of Health, Indianapolis, Ind.

So far so good, and if one important factor had not been overlooked no harm, except the loss of the water, would have resulted. But the water main happened to be under a very low pressure, 18 to 20 pounds perhaps, it being a low pressure main from the wells to a booster pump. The hill on which the pond had been created, also just happened to be high enough that when the booster pump was pulling hard, a negative head developed at the point where this valve had been cracked. When this negative head developed, the hogs were somewhat discommoded for the pond almost disappeared.

About that time, a sample of this city water was submitted to the Water and Sewage Department for examination. It was found to be contaminated, as were several other subsequent samples. Several investigations were made, and finally this pond was discovered, the connection closed, the mains flushed, and all was well. The matter was not made public, no one was excited, and luckily no sickness resulted.

In the case of public water supplies I shall bring to your attention, somewhat in detail, only those cases in which the health, as well as the wealth of a community are involved.

By so limiting the scope of this paper, I do not wish to belittle the effect of inadequate fire protection upon the growth and industrial expansion of a city or town. No place can hope to reach its ultimate development industrially or socially, until adequate fire protection is provided at all times.

The water shortages that occur in a number of cases are due to a city outgrowing its water supply. What originally could be considered an adequate supply, becomes pitifully inadequate when the city doubles in size. In these cases, it sometimes takes a severe jolt to bring the "powers that be" to a realization that their city has outgrown its water supply and that money must be spent to make the supply meet the demand. A shortage also often exists because of the fact that a populace demands that an inadequate ground water supply be utilized in preference to a treated surface supply, since they think that they do not want any chemicals added to the water that they drink.

Other places, lacking even an adequate surface water supply, face the necessity of coping with a falling ground water level. Table 1, prepared some years ago by Mr. Brossman, and which I am using with his permission, clearly shows how the ground water level has fallen in several individual wells, in a surprisingly short time. These figures are given, not to show actually what is happening at present, but to indicate the trend of ground water levels in many wells. No doubt comparable figures could be given showing the same or greater drop in recent years.

It should be noted that since this table was originally prepared by Mr. Brossman, Muncie has given up trying to get sufficient water from wells and has installed a plant to treat the White River water.

In other cases, where water from a natural or artificial lake is used, a long dry season creates a situation that renders drastic steps necessary. In such cases, an emergency supply is brought into use that more often than not is of such quality that the existing means of treatment cannot render it potable. It is only the grace of God that prevents a severe outbreak of typhoid or other intestinal disturbance.

TABLE 1

TOWN	DROP OF WATER LEVELS IN SOME WELLS	LENGTH OF TIME FOR DROP TO OCCUR
	feet	*years*
Kentland	48	5
Elwood	40	12
Greensburg	40	10
Muncie	28	Not given
Remington	8	10
Marion	6	20
Butler	4	10
Bourbon	3	8½
Linton	30	6
Kokomo	15	15

Such a situation existed during the past summer at Huntingburg. Huntingburg ordinarily draws its public water supply from two artificial lakes. This supply at best can in no way be regarded as satisfactory for drinking purposes, since the only treatment which it receives is the natural sedimentation that occurs during the storage in the lakes. Due to an unprecedented shortage of rainfall on the watershed of these lakes, they became dry, or practically so, early in June. All industries in the town were shut down until a temporary pipe line could be laid to the Patoka River, several miles away. The people were warned of the condition of the water that was in the mains and in general private supplies were used until late in the fall, when sufficient water had accumulated in the lakes.

It is stated that no serious outbreak of typhoid occurred during this period, but immediately after the emergency supply was discontinued, and the lake water again turned into the mains, an outbreak of a peculiar type of intestinal "flu" occurred. It cannot be said conclusively that this trouble came from the water, but the indications point that way, since the outbreak seems to have been confined to the town itself. This can only be considered a coincidence, since no actual investigation that would conclusively point to the water was made.

In this situation at Huntingburg another means of endangering the public health, through a water shortage, should be noted. In this case, as in others, the first step that the people took after being notified to boil the water, was to begin utilizing private wells of doubtful quality. A survey of the private wells was made by the health officer and a majority were found to be unsatisfactory. This is usually the case in built up sections.

Of the large cities in Indiana, Fort Wayne suffers the greatest water shortage. The water supply there is drawn from approximately 50 wells, from 6 to 10 inches in diameter and from 250 to 1200 feet deep. During the past summer, there were times when to conserve a sufficient supply of water in the reservoir, for an emergency, it was necessary to leave parts of the city virtually without water. Since that time, one additional well of the Layne and Bowler type, has been completed, and another is under construction. The contractor has guaranteed a flow of 2,000,000 gallons from these wells. It remains to be seen, however, whether these wells will relieve the situation.

At Richmond, last summer, a shortage occurred that involved almost every type of water supply that has been developed in Indiana. Richmond impounds the water from springs and draws water from wells and infiltration galleries. To relieve the situation, water from a small creek was pumped into the mains. Since the supply at Richmond is chlorinated, and great care was taken at that time that the dosage meet the varying conditions, no unsatisfactory samples of water were received by the Water and Sewage Department. Nevertheless as an added precaution, the people were warned to boil the water.

Another situation exists, in several cities in the state, that constitutes a potential danger to the health of the residents. In these places, there is ordinarily an adequate supply of water for domestic and industrial purposes, although the supply would be inadequate in case of a large fire. As an added fire protection, ponds that can be pumped into the mains in case of emergency, are maintained. Usually no effort is made to protect the sanitary quality of the water in these ponds, and if it ever becomes necessary to use the water, a serious epidemic is likely to arise. It is said that in at least one case, dead cats, dogs, and other refuse are thrown into the fire pond.

In this state, there are seven towns which do not even pretend that the public water supply is safe for drinking purposes. You will note that I have referred to these places as towns and not as cities. In my own opinion, no place in which the public water supply is not fit to drink, should be classed as a city. Petersburg, a community of about 2500 people, and county seat of Pike County, pumps raw Patoka River water into the mains. Probably few of the inhabitants drink the water, but it is always possible for strangers to drink it.

Vevay, county seat of Switzerland County, uses raw Ohio River water although a well supply is available. The people prefer the river water because it is soft. The water is not universally used for drinking purposes, although some residents use it and one doctor will argue that no harm comes from drinking the water (although he does not drink it himself).

Batesville, 2500 population, uses impounded surface water without any treatment.

Marengo, a town of 800 people, uses, without treatment, the water from surface springs in a limestone formation. In 1919, at one time, 35 individuals were being treated for an intestinal "flu" that was diagnosed in many cases as typhoid fever. Since that time other typhoid epidemics have occurred. Private wells in Marengo, being in the same limestone formation as the springs, were almost universally found to be contaminated.

Hazelton, a town of 600 people, located in Gibson County, uses untreated water from White River almost universally for drinking purposes.

All of these places to which I have already referred are located in the southern part of the state, but it must not be supposed that such conditions are confined to that portion.

Winamac, a town of 2,000 people, and county seat of Pulaski County, one of the northern counties, pumps untreated water from the

Tippecanoe River. It is not generally used by the inhabitants for drinking purposes, although it is possible for a stranger to drink the water without knowing that it is unsafe.

Rochester, a resort town of 4000 people, and county seat of Fulton County, furnishes its inhabitants with untreated water from Lake Manitou. This water is not regarded as satisfactory for drinking purposes and is not used generally for that purpose, but it is available for such use.

If the people living in these seven towns just mentoned, do not bestir themselves, and treat their public water supplies, it is only a question of time until an epidemic of typhoid will force them to act, but it will then be too late to prevent the suffering and economic loss that accompanies such an epidemic.

Other cities and towns, when faced with a water shortage or with the necessity of treating an unsafe supply, have gone ahead and made the necessary improvements, although in many cases heavy burdens have thus been placed upon the tax payers or owners.

Within the last few years, Bloomington, Valparaiso, Mishawaka, Boonville, Edinburgh and many other places have made improvements that have at least rendered their water supplies adequate for some years to come.

In closing, I wish to remind you of one "horrible example" of what can indirectly arise from an inadequate water supply.

At the resort town of Winona Lake last summer, because of an unusually large crowd attending a convention, it became necessary to flush some public toilets with water from a private untreated surface water supply, in order to conserve the public supply.

In order that water would be available for flushing the toilets, in case the private supply should fail, a cross connection with the city water supply was maintained. The details of this case are immaterial, but by some means or other this connection between the two supplies was opened, and the surface water pumped into the mains.

Between 500 and 1000 cases of typhoid fever, scattered over almost all of the States east of the Mississippi River resulted.

What happened to Winona Lake can happen, in a smaller way perhaps, to any city or town in Indiana, that does not provide an adequate, safe water supply. In all cases, before an acute shortage develops, the situation should be thoroughly studied and the necessary steps taken to provide an adequate safe water supply.

DISCUSSION

Howard A. Dill:[3] Mr. Finch's very interesting and important paper on water shortage in Indiana is a timely one, after the experience of many water companies in 1925.

This subject can be discussed in two phases. One, a water shortage due to controllable factors, such as indifference and lack of foresight, difficulty in financing needed additional water developments, pumping facilities, filtration units, distribution feeders, etc. The other phase is that of water shortage due to uncontrollable factors, such as unusual deficiencies in rainfall, as in 1925.

The first difficulty can be solved by a careful consideration of facts based on growth of the town or city supplied, increase of consumption, reduction of waste through inspection or metering, thereby determining the probable requirements for a number of years ahead. The financing of improvements can be met by new issues of stocks or bonds, if the revenues justify. If rates are too low to give proper income, hearings before the public service commission will usually result in a proper rate schedule being authorized.

A presentation of the facts to the newspapers, city officials, and business organizations will generally secure their endorsement and coöperation of such procedures, for the people are vitally interested in a pure and adequate supply of water. Too frequently such improvements are deferred for political reasons and public opinion is a valuable incentive for prompt action.

The uncontrollable phase due to an unusual lack of rainfall reducing the sources of supply is a more difficult problem. Yet these situations may be forecasted or anticipated to some extent. All sources of supplies are more or less affected by a variation in rainfall, whether they be rivers, lakes, springs, wells, or galleries. The amount and rapidity of run-off on water sheds has a greater influence on springs, wells and galleries than on rivers and lakes, and should be taken into consideration. Moderate rainfalls evenly distributed through the year will replenish underground sources to a larger degree than will excessive precipitation in a short period of time.

The Water Company at Richmond has been a Government Weather Bureau station for over thirty years, taking daily readings of rainfall, snowfall and maximum and minimum temperatures.

The record for the first eight months of 1925 gave a precipitation of 18.18 inches. A thirty year average for the same period was 27.64, giving a shortage of 9.46 inches. This seriously affected the sources of supply, which are infiltration galleries, springs and wells. All supplies take water from gravel strata located from fifteen to twenty feet below the surface.

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[3] Superintendent, Water Works, Richmond, Ind.

Due to the geological conditions (Richmond being on an anticline, and underlaid with limestone), it is not possible to secure water below the rock. The shortage of rainfall reduced the capacity of the supplies about 25 per cent. Four new wells having a daily capacity of 1,300,000 gallons were not sufficient to meet the demands and it was necessary to pump from a stream for a period of a week or ten days and to eliminate all sprinkling. This was the first time in forty years that such restriction was necessary.

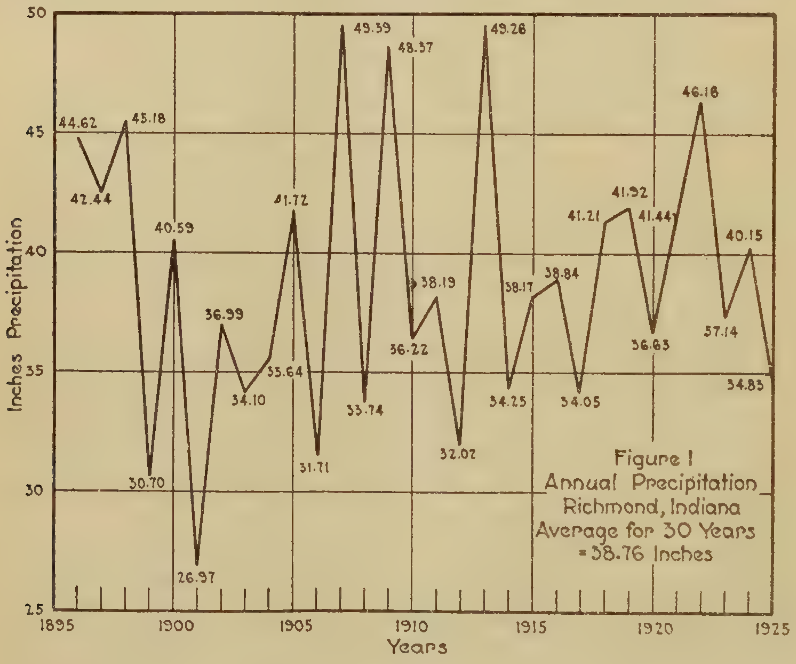

FIG. 1

By careful chlorination under the supervision and daily tests of the State Board of Health, the water was made safe for drinking, and no sickness resulted. The city health officer advised boiling, and many consumers obtained drinking water from nearby springs, although all tests of the city water were satisfactory. The rainfall for 1925 was 34.83 inches or 3.93 inches below the thirty year average.

Figure 1 gives the annual precipitation from 1895 to 1925, the average being 38.76 inches.

In financial and business circles, charts are used to indicate the trend of prices and to forecast the general business conditions, and prices of stocks, bonds, commodities, etc. Does the rainfall chart here shown give a means of predicting or assuming that the precipitation for 1926 will be above or below the average?

We believe it does. With the exception of upward trends in 1905, 1911, 1916 and 1919, all lines show a successive upward or downward movement. There are no two successive downward movements. Therefore, the chart indicates that in 1925 the probabilty was for a downward movement, or a shortage, or, at last, only a slight upward movement. For 1926, following the tendency shown on the chart, it can be assumed that the movement will be upward, especially as 1925 closed with a deficit of nearly four inches below the thirty years average.

Sources of supplies will be replenished and there will be less probability of a shortage of water. However, as this is an uncontrollable factor, no water plant should jeopardize life and property by a failure to provide an adequate supply, and filtration and pumping facilities.

SUPER-CHLORINATION OF CHLOROPHENOL TASTES

By Louis B. Harrison[1]

The question of chlorophenol tastes in city water supplies has become a serious one. Cities in many states throughout the Union have been suffering from these tastes. Through many experiments it has been definitely demonstrated that these tastes are caused by a combination of chlorine and phenolic wastes. The remedy suggested for getting rid of them was to keep them out, and I still believe that it is the best remedy, if possible. However, in spite of all precautions taken by industries to keep these wastes out of the streams, they make their way into them, owing to the proportionately small quantity necessary to produce the taste. During the months of November and December 1925, we got doses of chlorophenol tastes in the Bay City filtered water supply, and during my investigation of the causes of these tastes I have found that an excess of chlorine destroys them.

I started experiments to find out the possibility of using super-chlorination as a means of destroying these tastes. I decided to try it out on pure phenol and also on wastes from gas works and wood distillation plants. All my experiments have been conducted at room temperature and filtered water was used in making dilutions. All tests have been made according to the standard methods of the A. P. H. A. The question of tastes was a delicate one, for what would seem very faint to one, would appear strong to others and vice versa. I have, therefore, reported, as taste, an average taste as detected by my assistant and myself. All experiments have been checked many times, and only after several months of experimentation have I put down the final results. I have selected the maximum concentrations, 1:10,000, in an arbitrary manner, assuming that this may represent the maximum concentration of waste we may possibly get at our plant.

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EFFECT OF SUPER-CHLORINATION ON CHLOROPHENOL TASTES

In order to determine the effect of super-chlorination on dilute phenol solutions, I have prepared various dilutions of phenol, starting with 0.01 p.p.m. and gradually increasing the concentration to a maximum of 0.075 p.p.m. To these dilutions of phenol I have added varying amounts of chlorine, and after standing for thirty minutes I tried them for tastes. Table 1 shows the results of the maximum concentration of phenol used when treated with varying amounts of chlorine. Chlorophenol tastes made their appearance with 0.125 p.p.m. of chlorine and then disappeared at 0.5 p.p.m. and again reappeared on increasing the amount of chlorine to 0.8 p.p.m. and disappeared entirely at 1 p.p.m. Any further increase of chlorine up to 2 p.p.m. had no effect. No tastes appeared in all negative samples after standing for twenty-four hours.

TABLE 1

Effect of super-chlorination on a dilute phenol solution

Number of bottle	1	2	3	4	5	6	7	8	9	10
Cl added, p.p.m.	0.05	0.50	0.075	0.10	0.125	0.150	0.175	0.200	0.225	0.250
Taste after ½ hour	0	0	0	0	VF	F	F	D	S	VS
Number of bottle	11	12	13	14	15	16	17	18	19	20
Cl added, p.p.m.	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
Taste after ½ hour	VS	F	VF	VF	0	0	0	0	0	0
Number of bottle	21	22	23	24	25	26	27	28	29	30
Cl added, p.p.m.	0.80	0.85	0.90	0.95	1.0	1.25	1.50	1.75	1.90	2.00
Taste after ½ hour	VF	VF	S	F	0	0	0	0	0	0

SUPER-CHLORINATION OF GAS WORKS AND WOOD DISTILLATION WASTES

Satisfied with the results on dilutions of pure phenol I extended my research on wastes from gas works and wood distillation plants, and performed a series of similar experiments on these wastes, using phenol in dilution of 0.075 p.p.m. as a check. The gas wastes were obtained from the Consumers Power Company at Zilwaukee, Mich., and the wood distillation wastes from the Du Pont E. I. de Nemours & Company, Bay City. Table 2 shows the results of these experiments with maximum concentration of the wastes used (1:10,000). With 0.6 p.p.m. of chlorine all samples, except wastes from wood distillation 2–3, produced chlorophenol tastes. With 0.8 p.p.m. phenol dilution and gas wastes produced tastes and with 1.2 p.p.m. of chlorine no tastes developed in any. Since experiments have shown that chlorophenol tastes increase in intensity on standing I let the bottles stand for twenty hours and then tasted them again. No taste developed in any of the bottles that were treated with 1.2 p.p.m. of chlorine.

TABLE 2

Effect of super-chlorination on wastes from gas works and wood distillation plants

	PHENOL (0.075 P.P.M.)			GAS WASTE (1:10,000)			WOOD DISTILLATION (1:10,000)		
Number of bottle	1	2	3	1	2	3	1	2	3
Cl added, p.p.m	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Taste after 30 minutes	VF	VF	VF	S	S	S	F	0	0
Res. Cl, p.p.m	0.6			0.4			0.4		
Cl added p.p.m	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Taste after 30 minutes	0	VF	0	F	F	F	0	0	0
Res. Cl, p.p.m	0.8		0.6				0.6		
Cl added, p.p.m	1	1	1	1	1	1	1	1	1
Taste after 30 minutes	0	VF	0	D	D	0	0	0	0
Res. Cl, p.p.m	0.8			0.6			0.6		
Cl added, p.p.m	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Taste after 30 minutes	0	0	0	0	0	0	0	0	0
Res. Cl, p.p.m				1.0	1.0	1.0			
Taste after 20 hours	0	0	0	0	0	0	0	0	0

REMOVAL OF EXCESS OF CHLORINE

From the results obtained it became evident that in order to destroy the chlorophenol tastes a considerable dose of chlorine is required. This dose will vary with the concentration of phenols in the wastes, as seen from table 2. Where 0.8 p.p.m. was sufficient to destroy the taste in wood distillation, it required 1.2 p.p.m. to bring about the same results in gas wastes, using the same concentration. In all cases a considerable amount of residual chlorine is left and to remove this excess of residual chlorine I have resorted to sodium sulfite. The reaction between sodium sulfite and free chlorine in an alkaline solution is

$$Na_2SO_3+H_2O+Cl_2 \rightleftarrows Na_2SO_4+2HCl$$

The sulfite is oxidized to the sulfate and the (HCl) hydrochloric acid reacts with the bicarbonates of calcium (Ca) and magnesium (Mg) liberating CO_2. From the above reaction the amount of sodium sulfite necessary to remove the excess of residual chlorine can be calculated. Instead of sodium sulfite, (SO_2) sulfur dioxide may be used, but in all experiments conducted by me Na_2SO_3 was used.

TIME REQUIRED FOR REACTION

It was then necessary to determine the minimum time required for the reaction between the chlorine and the phenolic wastes before the Na_2SO_3 could be added. Table 3 shows the results of the experiments conducted. After adding 1.2 p.p.m. of chlorine to dilutions of phenol, gas waste and wood distillation waste, mixing and letting stand for 30 minutes, sodium sulfite was added to 3A samples and twice the amount to 3B and then tasted after one hour. All 3A's and 3B's except 3B from gas wastes developed chlorophenol tastes and all others to which no Na_2SO_3 was added did not. Sodium sulfite was then added to all 2A's and 2B's, excepting phenols, and tasted after one and one half hours. None produced the taste.

TABLE 3

Reaction time between chlorine and phenol

	PHENOL (0.075 P.P.M.)				GAS WASTE (1:10,000)						WOOD DISTILLATION WASTE (1:10,000)					
Number of sample	1a	3a	1b	3b	1a	2a	3a	1b	2b	3b	1a	2a	3a	1b	2b	3b
Chlorine added, p.p.m.	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Na_2SO_3 added after 30 minutes cc.		1		2			1			2			1			2
Taste after 1 hour	0	F	0	F	0	0	F	0	0	0	0	0	F	0	0	F
Na_2SO_3 after 1 hour						1			2			1			2	
Taste after 1½ hours					0	0	F	0	0	0	0	0	F	0	0	F
Na_2SO_3 after 2 hours	1				1						1					
Taste after 2½ hours	0	F	0	F	0	F	F	0	VF	0	0	0	0	0	0	F
Taste after 24 hours	0	F	0	F	0	S	S	0	F	F	0	0	0	0	0	0

Na_2SO_3 was then added to all 1A's after 2 hours leaving the B's for blanks. None of the 1A's developed any taste after two and one-half hours. After twenty-four hours the tasting was repeated. All blanks were negative for taste. All samples to which Na_2SO_3 was added after thirty and sixty minutes produced tastes after twenty-four hours, whereas, in those to which the Na_2SO_3 was added after two hours no taste developed after twenty-four hours. It therefore appears that the minimum time required for the reaction between chlorine and phenolic wastes is at least two hours and the sodium sulfite to produce proper results should not be added any sooner.

THE pH EFFECT

The effect of the pH value on the formation of the chlorophenol tastes is a subject that must be studied. Inasmuch as these tastes occur in Bay City's water supply during the sugar campaigns, and the alkalinity of the water is highly increased, it is quite possible that this increase in alkalinity facilitates the reaction between chlorine and phenolic substances.

TEMPERATURE EFFECT

Experiments conducted by me recently at 38°F. indicate that at a low temperature a larger dose of chlorine is required and a longer period of reaction.

CONCLUSIONS

From recent inspections and investigations, I think that the problem of keeping out phenolic wastes from the streams is a complex one, owing to the fact that relatively small quantities are sufficient to pollute a large volume of water. No disposal system for these wastes can be made 100 per cent efficient.

Super-chlorination may aid a great deal in removing these tastes and as far as laboratory research is concerned, it gives very encouraging results. It is, however, questionable in my mind whether it will work out on a large scale in practice where temperature complications may present themselves.

To me it seems that a part of our research should be bent upon finding some substitute for chlorine, irrespective of cost, if only not prohibitive and to apply this germicide during periods when super-chlorination fails and chlorophenol tastes occur.

PREVENTION OF PHENOL TASTE WITH AMMONIA

By J. W. McAmis[1]

The water supply for Greeneville, Tenn., was established about the year 1889, the water being pumped from a bold limestone spring, which issues from under a limestone ledge, near the center of the city. This spring is still used as the source of water. It seems evident from the quantity of water afforded that only a small portion can have fallen on the immediate catchment basin, and that the major portion must flow underground for a considerable distance. However, all the water must flow under a rather thickly populated area to reach the location of the spring, and is consequently subjected to contamination with about every kind of objectionable waste.

Under these conditions it is not surprising that typhoid epidemics occurred more or less frequently among the water consumers. Several of these epidemics visited the city before 1912, when chlorination was resorted to in an effort to check them. This was the beginning of the obnoxious tastes that have appeared from time to time in the tap water, causing some of the water users to demand that the chlorination be stopped. The chlorine has always been blamed entirely for these tastes and odors. This assumption is at least partly correct. The writer is reliably informed that they had never been known in the twenty-three years prior to the advent of chlorination. One employee of the water works, the pumping engineer, states that the trouble began about that time and that it has never been noted in the raw water. He also is positive that it has never been present in the freshly chlorinated water. This employee has been continuously in the employ of the water works since the beginning. These facts would indicate that the taste producing substance, if present in the raw or unchlorinated water, requires considerable time, after the entrance of the chlorine, before the reaction is sufficiently complete to produce the phenol like tastes and odors.

The term phenol taste is used here because, as near as it has been

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possible to determine by tasting the water, this trouble is the same as that experienced in water known to be polluted with phenols. During the past summer three persons, who have used the Ohio river waters reported to be polluted with phenolic wastes for considerable periods, have been in Greeneville, and have had ample opportunity to compare the taste of the Greenville tap water with that of their home towns. These persons are all positive that they can detect no difference. There have been two occasions in the last six years when the taste was extraordinarily severe and it was possible to prove the presence of phenol. The first was caused by painting a standpipe with coal-tar paint, and the second occurred when some disinfectant was dumped where it found its way into the waters of the spring. The citizens of Greeneville, therefore, are somewhat familiar with what is known to be phenol taste. This taste can be duplicated by dosing samples of water with minute quantities of carbolic acid, though the writer thinks that cresol produces a taste more nearly characteristic.

The first chlorine apparatus used calcium hypochlorite for making the sterilizing solutions, and as there was no technical supervision, the regulation of the dosage was necessarily poor. In fact it was so poor that two typhoid epidemics occurred after the apparatus was installed, showing that sterilization was not always accomplished. Poor regulation has been thought to be the cause of these tastes and odors, by others who have investigated along this line. This, however, as will be shown later, cannot possibly have been the case in Greeneville.

In 1917 a standpipe was erected, creating storage equal to about one day's supply of water. If, as suggested above, the time elapsed between the entrance of the chlorine into the water and the using of the water is an important factor, then the increased storage should have been instrumental in increasing the prevalence of the taste. The records are not sufficient to show whether this was true at the time or not. In 1923 another standpipe was erected, doubling the amount of water in storage. This additional storage was put into service the latter part of 1923 and during the succeeding summer and the summer of 1925 complaints were much more numerous. During 1924 facilities for softening, coagulation and filtration were also put into service. These features permitted much closer regulation of the dose of chlorine, due to the fact that an ideal point was now available for the application of the liquid chlorine (liquid chlorine had been substituted for the hypochlorite in 1920). At this point (filter effluent) the flow of the water is uniform, the mixing is excellent and the rate of flow is indicated accurately by venturi meter.

ALGAE VS. TASTE

About this time it was suggested that blue green algae, which had been growing in the spring and immediately started to grow in the new settling basin, were responsible for the tastes and odors. The consulting engineer had specified covers for both the spring and the standpipes, partly because of this growth. Copper sulphate was used on the settling basin, but applications became necessary so frequently that it was finally also covered. This stopped the algae growth but failed entirely to abate the taste nuisance.

CLOSE REGULATION VS. TASTE

A laboratory was equipped for the new filtration plant, and it now seemed that, if there was any merit in close regulation, or in maintaining any particular dose or residual in the water after sterilization had been effected, we should be able to find the way to operate without being troubled with the chloro-phenol taste. Experiments with the idea of getting just the right dose were carried on during the entire summer and fall of 1925. The dose was reduced, so as to be just sufficient for sterilization (about 0.1 p.p.m.). It was then gradually increased to a maximum of about 1.0 p.p.m. without any apparent change in the intensity or the frequency with which the taste appeared. It may be noted here that only a relatively small portion of the total water delivered from the plant bore this taste. It seemed to appear in spots as one writer has aptly expressed it. The writer has noted it in his own home, and frequently, though not always, on drawing water from the next spigot down the street the taste would be entirely absent. Nothing that was done in 1925 seemed to have any effect on this troublesome matter. We were able to make conditions neither better nor worse, although the taste apparently cleared up of its own accord when cold weather began. No complaints occurred from December, 1925, up to about May 1, 1926.

TESTS FOR PHENOL

In the meantime reagents were assembled for making both the Fox and Gage and the Folin-Dennis tests for phenol, in order that tests might be made daily, endeavoring to show whether the water was only occasionally polluted and thus account for the intermittent appearance of the taste in the tap water. Samples of the raw, the filtered (before chlorination), the chlorinated, and the tap water from about the city were examined in this way. Some of the tap water which very definitely had acquired the taste was also tested for phenols. A very doubtful reaction was obtained at times, although no relation could be established between the color appearance and the phenol taste in the water. About 200 samples were examined and having gained no definite or useful information, this work was abandoned.

HOUSTON'S REPORT

The writer was fortunate to obtain a copy of the nineteenth annual Report of Sir Alexander C. Houston, Director of the Bureau of Water Examination, Metropolitan Water Board, London, England. In this report the work of Adams (in England) and Harrold (in India), regarding phenol tastes in water was described. This work (Houston and Adams) established definitely the fact that it is possible for water to become so contaminated from contact with the air in industrial districts as to give the "iodoform" taste. Attempts were made to perform some of the experiments on portions of the Greeneville water, with the idea of showing such pollution of the water supply, but all gave extremely doubtful or negative results. This was to be expected as Greeneville is situated in an agricultural district, surrounded by mountains, and with no industrial plant within a radius of 30 miles, where it is possible for phenols to be produced. The possibility of industrial waste is also eliminated, for the water supply for Greeneville issues from the ground at an elevation somewhat higher than any industrial plant in the surrounding country.

TEMPERATURE VS. TASTE

Many samples were examined during the past summer (1926) in an attempt to learn what effect, if any, the increased temperature of the water in summer would have on the formation of the taste. No definite conclusions can be drawn from the data accumulated, due to the fact that the temperature of the water in the upper portions of the standpipes reached a much higher value than any observed in samples taken directly from the mains. Due to our system of operation and the layout of the piping, it was never possible to tell whether the particular water under consideration had not at some previous time been stored in the standpipes and had reached the higher temperature. With both standpipes in service and consequent longer period of storage, the maximum temperature reached by the water in the upper portions of the standpipes was 29°C. The minimum temperature observed at the bottom during the warmer months was as low as 17°C. The water having reached the higher temperatures would of course not mix readily with the colder water being pumped in at the bottom and would remain probably in the standpipe until the colder weather had reduced its temperature below that of the incoming water. This fact explains to some extent the unsatisfactory conditions, with regard to the taste of the water, existing principally in the summer and fall, and also why the trouble does not appear until late in the spring. One of the standpipes was cut out of service about the first of August in an attempt to lower the temperature of the upper layers of water, and by alternately drawing the water down low and pumping it up again, the upper temperature was lowered to 23°C. This may have brought about some slight improvement in the taste conditions, although it may have been one of the unexplicable periods of improvement, which had often occurred before. Leaving out of consideration, the possibility that the Greeneville water is in some manner polluted with a taste forming substance in summer, and that this substance is absent from the water in winter; it appears to the writer that the higher temperatures reached during the former season must have some bearing on the formation of this taste. If this is true, then the temperature at which the taste producing substance is formed lies between 17° and 23°C. There is, of course, the possibility of phenolic substances being dissolved from the pipe coating. The mineral content, however, of the Greeneville water is such that a slight scale of limestone is formed inside the pipes, consequently shutting the water off from contact with the pipe coating after a few months. Tastes have been noted which have undoubtedly been due to the installation of new piping, but these have only lasted for a few weeks and have ceased long before the carbonate coating has had time to form. Until some proof to the contrary appears, however, the possibility that the pipe coatings become more soluble in warmer water must always be considered, although this is thought to be a remote possibility by the writer.

RESIDUAL CHLORINE VS. TASTE

Nearly all the samples examined were tested for residual chlorine at the time of sampling. This was done in order to learn what relation, if any, existed between the taste and the residual chlorine as evidenced by the o-tolidin test. Tabulation showed that about half the samples which had acquired the taste showed no residual chlorine, while the remainder showed varying amounts, ranging from zero up to as high as 0.13 p.p.m. Many samples showed larger amounts, but none of those examined had acquired the taste when larger amounts were present. Several of the samples tested zero for chlorine, but had no taste. Many of the samples were kept in glass jars, at room temperature, for some time, but no material change was evident. Those which had developed the taste at the time of sampling retained it for a long time, and the taste would not develop under these conditions when it was absent from the original sample.

DOUBLE CHLORINATION

Another fact worthy of note was brought out at this time; namely, that when a sample of water which had definitely acquired the taste was treated with a very slight (second) dose of chlorine, the taste disappeared almost instantly. This seemed to be true whether the original sample had shown residual chlorine or not. The taste did not return even after the chlorine from the second dose could not be detected with o-tolidin. This of course suggested that double chlorination might be beneficial. When this was attempted on plant scale, however, it failed to show any improvement, probably due to the fact that the first dose, which was applied to the raw water as it entered the plant, had not caused any taste to develop before the second dose had to be applied. This was necessary of course before the water was delivered into the distribution system. The second dose was applied to the suction side of the high service pump.

PRE-CHLORINATION

In chlorinating the raw water, the chlorine was first applied to the water just ahead of the softening and coagulating chemicals. In fact, they all entered the water almost at the same time and the same place. This method spoiled the sterilizing effect of the chlorine, probably due to the formation of chloride with one of the other chemicals, although it was not determined at the time just what the trouble was. The chlorine worked beautifully when applied after the water had had a few minutes contact with the other chemicals. No change could be noted in the taste of the water delivered to the consumers while chlorinating the raw water.

CURATIVE MEASURES CONSIDERED

After being convinced that none of the above described methods could be relied on to give relief, methods of stopping the taste by the additional treatment with more chemicals, began to receive consideration. Super-chlorination with de-chlorination appeared to be the favorite method of Houston. The necessary chemical (SO_2) with which to accomplish the de-chlorination was not readily available, so this method was discarded temporarily. Treatment with potassium-permanganate is also well spoken of by Houston in his reports, but this has the disadvantage of being an active poison, and is likely to color the water unless careful regulation is maintained, so it was also passed temporarily. The only alternative then was the ammonia treatment which had been used successfully by Adams on a plant scale, and had been shown by Houston, in laboratory experiments, to have considerable merit as a "taste preventer." Preliminary calculation based on the amounts thought necessary by Houston, and quotations hurriedly obtained, indicated that the ammonia might prove the less expensive. Moreover the ammonia gas condensed in steel drums was available in the city. For these reasons it was decided to try it first.

AMMONIA USED TO PREVENT TASTE

This treatment was started on August 20, 1926, and the results have been highly satisfactory from the first. It was started while the raw water was still being chlorinated and the ammonia entered the water just ahead of the softening and coagulating chemicals, in fact at the same place that had previously proved unsuccessful for feeding the chlorine. This gave excellent results and was continued in this manner for about two months without change. The use of ammonia for prevention of chloro-phenol tastes and odors seemed to the writer to be rather a novel procedure and considerable doubt was entertained at first as to its value. However, Adams states that this (taste producing) reaction does not occur when the organic nitrogenous content of the water is high. Great improvement was reported in Milwaukee, when the industrial waste known to contain the taste producing phenols was mixed with raw domestic sewage. In the light of the experience of Adams, Houston and Harrold, and more recently in Greeneville, it seems reasonable to suppose that the organic ammonia of the raw sewage was responsible for the improvement noted. Nevertheless the writer was still doubtful that the ammonia was entirely to be credited with the improved taste of the water. Several persons accustomed to drinking the spring waters in the vicinity of the city were closely questions, as to whether they could detect any unusual taste in the tap water. The reply was always negative. Still not thoroughly satisfied, the ammonia treatment was discontinued for a few days on three separate occasions. In three or four days the taste would appear in the water with unfailing regularity. When the ammonia treatment, however, was resumed the taste disappeared as if by magic, as soon as the system had had time to become clear of the potentially tasting water.

POINT OF APPLICATION OF CHLORINE

The most logical and convenient point for the application of the chlorine in the Greeneville plant is to the filter effluent. Consequently after about two months trial of ammonia treatment, together with chlorination of the raw water, the pre-chlorination was discontinued and the application of chlorine to the filter effluent was resumed. No change in the delightful taste was noted in the tap water so this is the method in use at present.

LAGGING CAUSED BY AMMONIA

A lagging of the sterilization was noted in the laboratory experiments by Houston, but this has not been sufficient to interfere with the proper sterilization of the water, as evidenced by daily bacterial counts on agar. B. coli has been totally absent from the daily samples examined at the plant laboratory. Houston also noted that the ultimate effect of the chlorine was somewhat enhanced by the use of ammonia. Due to the fact that the filtered water here is consistently of excellent quality, no favorable basis is afforded for comparison on a plant scale. The characteristic color appearance in the o-tolidin test is delayed two or three minutes by the ammonia, but after three months operation we have been unable to attach any significance to this fact.

FEEDING THE AMMONIA

In attempting to feed the ammonia into the water, we first tried to feed it through an ordinary W. and T. hand control chlorinator. This chlorinator had previously been successfully used to feed chlorine and probably contained some of the residue which has always been deposited by the chlorine. The attempt to use it for ammonia was a complete failure, due to the stoppage of all the gas passages with a bluish substance which turned black on exposure to the air. The writer is doubtful whether ammonia could be successfully fed through chlorine apparatus as now manufactured, due to the high solubility of ammonia and the consequent partial vacuum created where it goes into solution. The method of feed finally adopted was to prepare a solution of ammonia water in a spare solution tank, which was available, and to feed the solution through a constant head orifice box, with which the tank is equipped. The steel drum containing the ammonia liquid is placed on a scale platform, preferably elevated above the water level in the tank when it is full. The ammonia gas is allowed to run from the steel drum down into the water in the solution tank. The scale is used to determine when the desired quantity of ammonia has entered the water in the solution tank. It is desirable to run the ammonia into the solution through a one-eighth inch needle valve so that the flow may be closely regulated. The needle valve is slowly opened until a slight cracking noise is heard in the water. If the ammonia is fed too fast the water will be drawn up and over into the ammonia container. A solution tank equipped with a stirring device is used in Greeneville, but the high solubility should cause the ammonia to diffuse quickly through the water. No mixing device should, therefore, be necessary.

DOSE OF AMMONIA

Houston states that in the laboratory a dose of 0.2 p.p.m. of ammonia as nitrogen, appeared to be sufficient in all cases, and that 0.1 p.p.m. accomplished results in some cases. Experience in Greeneville has indicated that these figures are correct. Furthermore doses three or four times larger than the values given above have not been detected (by taste) in the tap water.

COST OF TREATMENT

The ammonia treatment as practiced in Greenville is very simple and inexpensive. The cost, at prices now quoted on ammonia, would be about $0.60 per million gallons of water treated. When the advantage of delivering a water always free from the phenol taste is considered, this cost would seem to be insignificant.

ESSENTIAL DAILY LOG DATA IN THE PUMPING STATION[1]

By Isaac S. Walker[2]

I believe it is the thought in dealing with this question to limit the discussion to the operations of the steam operated pumping station, and not attempt to cover the equally important questions of purification plant records and records of water sales.

The subject is a large one and is of the greatest importance to water works operators, particularly those operating the smaller plants. It is not a new subject and many articles dealing with this and related questions have appeared in the papers of this and other water works associations. In spite of these enlightening papers, however, there are many small water plants operating in this country which, it might be truthfully stated, keep no permanent records whatever of their operations, or their water sales under different rates and classifications. This situation has been improved materially, however, in the states under public service commission control, where annual reports to the commission are required.

The topic, as stated above, is a large and important one, and somewhat difficult to handle in brief topical discussion. The first word of the title, "essential," is one to think about. It is about as difficult to differentiate between essential and non-essential as it is to classify luxury and necessity. What is one man's luxury is another man's necessity. Similarly, what might be a non-essential in one water plant would be deemed an essential in another plant. But it is the history of civilization, that luxuries, by continued use become necessities, and water works records and statistics, which might at first be considered non-essential, by their continued use and demonstrated effectiveness, soon come to be considered absolutely essential. Properly kept records and data also tend to improve the plant morale and increase the attention and interest of the attendants. There is another important point in this connection. When operating records are maintained, there is always a tendency to improve the system. This leads invariably, under progressive management, to the introduction of recording instruments, which are necessary for the successful operation of a boiler room and pumping plant.

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[1] Topical discussion presented before the Buffalo Convention, June 7, 1926.

[2] General Manager, New Chester Water Company, Philadelphia, Pa.

Many papers on the value of such devices have been presented in this Association. In Volume 1, of the JOURNAL of March, 1914, page 103, our old friend Jack Diven, of revered memory, presented a valuable paper on the "Use and benefits of pressure recording gages." Mr. Diven, in his introduction, quoted from a paper by Charles A. Hague, presented in the Proceedings of this Association of 1891, page 77, entitled, "Value of pressure records in connection with water works." Mr. Hague, in turn, quoted Mr. Edwin Darling in his 1889 report of the Pawtucket, Rhode Island, Water Works, as follows: "No well conducted water works can afford to be without recording gages, and, when properly located, they will, in my opinion, pay for themselves within one year."

This statement was made thirty-seven years ago, and yet we find today many of the smaller water works without a single recording gage.

Throughout the country we find policies of operation and record keeping varying from very complete and more or less elaborate systems in some of the large plants to practically no records in many of the smaller plants. As an illustration of the first type, I would refer you to a paper entitled, "From coal to water,"[3] by our fellow member, George N. Schoonmaker, describing the operating methods of the Toledo Water Works. This plant is very thoroughly equipped with meters and indicating and recording devices, which are changed analyzed and computed daily by a trained employee, who, I would infer from the paper, devotes the major part of his time to his work. The illustration, on page 986 of Mr. Schoonmaker's paper, showing the chart desk containing some 16 charts as well as his log sheet on page 988, are of interest.

It is not to be expected that with the limited organization of the small or medium size plant, their records and analytical data of operations can be kept in the way Mr. Schoonmaker does it at Toledo, much as this might be desired. There is not a water plant operator in the country, however, who cannot afford, as the minimum of equipment of this character, one or more recording gages to furnish daily charts of the water pressure, steam pressure and vacuum.

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[3] Journal, November, 1923, p. 979.

His daily log should show all the essential facts relating to the plant operations, and should at least include

The names of the engineer and fireman on each watch
Pump counter readings at fixed intervals, of each pump
Counter readings at time of starting and stopping
Total revolutions
Total hours pumps are operated
Total pumpage
Pounds of coal used
Kind of coal used
Average B.t.u. per pound of coal
Hours of service for each boiler
Total ashes
Per cent ash
Average steam pressure
Average water pressure
Average vacuum
Suction and discharge heads in feet
Total head in feet
Average temperature of the weather, the boiler room, the feed water and the water delivered

If means permit, it will also be desirable for the plant operator to equip his station with some or all of the various devices for the detection of waste, and improvement of efficiency, among which might be mentioned:

A meter or meters showing the total plant output, or preferably the output from each pump
A boiler feed water meter
Draft gages for each boiler
A carbon dioxide recorder
Steam flow meters, or a measuring device for the condensate from each pump condenser
A recording tachometer to provide a record of the pump speed
Recording thermometers to provide a continuous record of the temperatures of the weather, the boiler room, the boiler feed water and the flue gases

The daily record charts from such recording instruments constitute the best kind of log data, and they should be carefully preserved in order and filed for permanent record. These instruments will, in most cases, be gladly welcomed by the attendants and they will relieve them from devoting their time at regular intervals, to the reading and recording of various indicator gages.

In preparing a schedule of log records for the pumping station, however, it must be borne in mind that in the average station, with possibly only one engineer and one fireman on a shift, these men have other duties than record keeping, so the system should be simplified as much as possible and should not be unduly burdensome. I am not in favor of systems such as I have seen in some stations, which require the inspection and tabulation of the readings of a multitude of indicating gages and other items every half hour or so out of the twenty-four. It is a foregone conclusion that this kind of attention will not be regularly given by the average engineer and fireman, particularly at night, and the readings and notations will be doctored and untrustworthy. This feature of possibly unreliable records of indicated readings, due to errors of reading, recording or doctoring, is eliminated by the use of recording gages.

In the average plant the cost of pumping constitutes the largest single item of operating costs. Is it not, therefore, the logical thing to keep apace with the times, eliminate guess methods, and equip our plants with modern instruments, by means of which the overall efficiency can be materially improved. The closing sentence of Mr. Schoonmaker's paper above referred to, is "Get your furnace a cash register." This is excellent advice.

I am strongly of the opinion that this topic is one which should be handled by a committee of the Association. I presume the subject properly comes under the work of the Committee on Pumping Station Betterments, and may possibly be considered by them. We also have the Committee on Essential Data for Water Records and Reports, which has given us an excellent form for such statistics for our annual reports. Log data reports of the pumping station are just as important, probably far more so to the little fellow. I am not familiar with the proposed future work of either of these committees but if this phrase of the subject has not been contemplated, it would seem to be desirable to give it their consideration.

Coöperation of existing committees is essential, as there has already been a duplication of effort, to some extent, in the work of overlapping committees. A solution for this case might be the appointment of a sub-committee of members of the two above committees, working with this Plant Management and Operation Division. Such a committee could render valuable service, particularly to the small works operator, in recommending a model form for keeping his log data, and forms for the weekly or monthly analysis of such data.

This suggestion is by no means new, and in this connection I would refer you to Earle L. Waterman's paper presented before the Iowa Section Meeting several years ago, entitled, "Operation records for small water works,"[4] in which he discusses the need of the small works operators for help of this character and expresses the view that such assistance would be greatly appreciated, and that a committee on operating records for small water works would find a large field in which to work. I am sure this suggestion is worthy of consideration.

In addition to the papers on this or related subjects, to which I have referred above, I would also direct your attention to the following:

Pumping Station Practice. Manual of Water Works Practice, 1925, p. 346.

Maxwell, D. H.: The water works coal pile. Jour. Amer. Water Works Assoc., November, 1923, p. 1072.

Cunningham, F. G.: Selection of auxiliaries for steam operated stations. Jour. Amer. Water Works Assoc., March, 1924, p. 341.

Gwinn, Dow R.: Instructions to employees at pumping stations and filter plants. Jour. New England Water Works Assoc., December, 1920, p. 284.

Behney, C. C.: The luxuries of yesterday are the necessities of today. Jour. New England Water Works Assoc., September, 1924, p. 294.

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[4] Journal, July, 1924, p. 819.

COST OF OPERATING MOTOR DRIVEN CENTRIFUGAL PUMPS AT McKEESPORT, PENNSYLVANIA[1]

By Leo Hudson[2] and A. J. Richards[3]

During the year 1924 the City of McKeesport let contracts for the extension of the filter plant and the electrification of the two high service pumping stations. The work was completed and tested in time to get accurate operating conditions beginning January 1, 1925 and the plant has been in continuous operation since that date. The city is divided into two water zones, the lower part being supplied by a reservoir and the upper part being supplied by a standpipe. The two old steam plants are closed except for emergency purposes and the two new pumping installations were installed in one pump room directly connected to the filter plant extension, each set of pumps discharging through separate pipe lines, one delivering the water to the low service reservoir and the other to the high service standpipe. The entire water softening, filtration and high service pump plants are combined under one roof. The city gets its main raw water supply from the Monongahela River through a pump plant located about two miles distant from the filtration and main high service pumping plants and with this exception the entire plant is now concentrated at one point. The cost figures given in this paper apply only to the high service pumping operation and is exclusive of the low lift raw water pumping operation.

The reservoir supplying the lower portion of the city with treated water is at an average operating head of 334 feet above the bottom of the clear well. The high service zone is at an average operating head of 555 feet above the bottom of the clear well. The average heads as herein stated are the weighted average dynamic heads taken from the charts at the pumping plant. Venturi water meters were inserted on each discharge line and accurate records have been kept of the pumpage, power factor, kilowatt hours consumed and the demand. It is from these data that we have figured the total cost to own and operate the new pump plant, finally reduced to the cost per thousand gallons of water pumped against the respective heads.

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[1] Presented before the Central States Section meeting, September 22, 1926.

[2] Of Hudson & Myron, Consulting Engineers, Pittsburgh, Pa.

[3] Superintendent of the Department of Public Safety, McKeesport, Pa.

During the first few months of 1925 the reservoir and the standpipe pumps were run in relay in order to keep the demand from being built up in terms of both pumps being operated at the same time. This method of operation, however, proved to be unsatisfactory to the residents in the high service zone in view of the fact that the fluctuations of head in the standpipe at the times of maximum hourly demand were such as to create a condition of slightly unsatisfactory service. To meet this demand it was finally decided on June 6, 1925 to run the pumps in parallel. This change in operation built up the demand, but of course required the same number of kilowatt hours of current consumed. At first the valves on the discharge lines were by-pass valves, but in terms of the type of motors installed it was found advantageous to change these valves for hydraulically operated valves for reasons which will be given later. This change will also warrant the reduction of the force in the pump room by two men per day after the change will have been completed.

In order to give some idea of the variation in the demand the following figures are given:

Percentage of each month of the total annual pumpage, 1925

January	9.1
February	10.0
March	7.0
April	8.0
May	8.3
June	9.2
July	8.0
August	10.8
September	6.6
October	7.4
November	7.4
December	8.2

During the year 1925, 2,046,457,000 gallons were pumped to the reservoir and 295,669,000 gallons to the standpipe. This gives a total pumpage of 2,342,126,000 gallons.

The monthly variation in the kilowatt demand and the kilowatt hour consumption was due to the foregoing monthly variation in the demand for water and the fact that a part of the time the pumps ran in relay and a part of the time the pumps ran in parallel.

Before the plant was designed, careful consideration was given to the type of equipment to install therein. Power was purchased from the Duquesne Light Company, after careful consideration had been given to the continuity of the source of supply. The circuit of the Duquesne Light Company, was such as to supply power from two main generator stations, one the Colfax Station and the other the Brunots Island Station. Tie-in circuits were also provided with the West Penn Power Company, system for current generated at the Springdale, Pa. plant and the new Cheat River development. This main circuit system is also tied in with the Pennsylvania & Ohio Power Company, which has stations at three different points. This constitutes a tie-in with the super-power circuit of Western Pennsylvania which can draw on main stations at Cleveland, Buffalo and Philadelphia. The sub-station for this plant is a loop station providing duplicate service from two different sub-stations in the Pittsburgh District. From the time the plant was started until the present date there has been only one interruption of service and that was due to a short circuit at the Colfax Plant which lasted for about forty minutes and until one of the other plants could be thrown into service. The current furnished by the Duquesne Light Company, is in terms of their rate "F" wholesale Light and Power. Under this contract the average cost of power has been ten and seven-tenth mills per kilowatt hour and ranging from sixty mills for the first 200 kilowatt hours down to as low as seven mills per kilowatt hour and in terms of the demand charge of $1.50 per month per kilowatt for the first 100 kilowatts of demand and $1.00 per month per kilowatt for each kilowatt in excess of 100 kilowatts. These bills then are subject to a prompt payment discount of five mills per kilowatt hour for all energy billed at 60 mills per kilowatt hour, two mills per kilowatt hour for all energy billed at 27 mills per kilowatt hour, one mill per kilowatt hour for all energy billed at 13½ mills per kilowatt hour and then there is a variable discount for power factor better than 75 per cent. At 100 per cent power factor this discount amounts to 8.819 per cent.

Before the type of equipment was decided upon serious consideration was given to induction motors of both the squirrel cage and the slip ring type with the power factor corrected by the installation of static condensers or synchronous condensers; and synchronous motors. Choice was finally made in terms of the synchronous motors because the first cost was found to be lower and for units of this size the operating cost was estimated to be less. The pumps for the reservoir are two stage series pumps while the pumps for the standpipe are four stage single suction multi-stage type of pumps. There are duplicate pumps for each installation and in order to get the installations in duplicate in so far as possible 500 h. p. motors were installed for each pump for each service. Some difficulty was experienced in the first months of the operation due to not being able to get the power factor meter properly registering and due to the fact that the valves on the discharge lines were by-pass gate valves and it was found advisable to replace them with hydraulically operated gate valves so that the motors could build up to synchronous speed before the valves were opened and the full load thrown on them with minimum amount of labor. This necessitated the closing and opening of each discharge gate valve in starting up each pumping unit and was satisfactorily done by man power, but by the installation of hydraulically operated valves the operating force will be reduced by two men per day, the third shift man being retained in the plant for general utility purposes. In other words, the labor required in closing and opening all the by-pass gate valves on the discharge lines each time the pump was started will be eliminated upon the completion of the hydraulic gate valve installation. At this time there is one hydraulic gate valve yet to be installed. In the cost tabulation herein included, therefore, the cost of operation includes these two additional men where when the hydraulic valve transition takes place entirely this force will be reduced and the cost of operating the plant correspondingly reduced. This change from the by-pass gate valve to the hydraulic gate valve is made therefore purely for the purpose of saving in the operating expenses the labor of two men per day. Finally therefore the cost of these two additional men per day is included in our cost figures, but not the cost of the additional hydraulic gate valve installation.

FIXED CHARGES ON THE COST OF THE PLANT

The contract for the four pumps and motors completely installed and tested was $27,500. The contract for the electrical work including switch-board, wiring and all other electrical equipment exclusive of the motors and exciters was $9000. Piping in pump plant and within two feet outside of pump plant $9500. The contract for the structural work below the operating floor that is, for the clear well under the pump plant, the pump pit, and the superstructure was $28,560.

The cost of the pump plant itself was as follows:

Pumps and motors	$27,500
Electrical work	9,000
Piping in the pump plant	9,500
Sub-structure and superstructure	28,560
Total	$74,560

The City of McKeesport sold the bonds for the pump plant improvements, the filter plant extension, pipe line extension and other works incidental to the general improvements at 4¼ per cent with a slight premium. This makes a fixed interest charge on the investment of $3169 per year or one and four-tenth mills per thousand gallons of water pumped. In terms of pumping 2,342,126,000 gallons the depreciation cost is ($0.0005) one half of one mill per thousand gallons of water pumped.

MAN POWER COST

The operating force of the combined new pump plant consists of one half the salary of the chief pumping engineer, the salary of three pumping engineers one for each eight hour shift and at the present time the salaries of three helpers. The chief pumping engineer receives a salary of $2260 per year, $1130 of which is charged against the main pump plant. There are three pumping engineers at $175 per month each or $525 per month or $6300 per year. There are three helpers at $150 or $450 per month or $5400 per year. The total man power cost therefore is $12,830 per year. The total pumpage as herein before given was 2,342,126,000 gallons. This therefore amounts to $0.00548 or practically five and one half mills per thousand gallons for man power.

The net cost of electricity for the entire year 1925 as shown in table 2 was $38,654 and for that amount 2,342,126,000 gallons of water were pumped to the reservoir and the standpipe. This makes an average power cost per thousand gallons of water pumped of $0.0165.

TABLE 1

Depreciation determination in terms of interest compounded annually at 4 per cent

	COST (NEW)	LIFE	AGE	FACTOR ANNUAL	FACTOR ACCRUED	ANNUAL CONTRIBUTION TO DEPRECIATION	ACCRUED DEPRECIATION	COST (NEW) LESS ACCRUED DEPRECIATION
Pumps and motors	$27,500	25	2	0.0240	2.040	$660	$1,346	$26,154
Electrical work	9,000	25	2	0.0240	2.040	216	441	8,559
Piping in pump plant	9,500	25	2	0.0240	2.040	228	465	9,035
Sub-structure and superstructure	28,560	50	2	0.0066	2.040	188	384	28,176
Total	$74,560					$1,292	$2,636	$71,924

TABLE 2

Summary of electrical data

DATE	KILOWATT DEMAND	KILOWATT HOURS	POWER FACTOR	LOAD FACTOR	NET BILL
				per cent	
January 2 to March 5, 1925	444	915,000	98.3	95	8,041.70
March 5 to April 5, 1925	444	259,500	98.6	81	2,690.80
April 4 to May 6, 1925	444	268,000	99.6	84	2,722.89
May 6 to June 6, 1925	444	261,000	100.0	82	2,661.29
June 6 to July 8, 1925	740	301,000	98.75	57	3,356.82
July 8 to August 5, 1925	750	277,000	100.0	51	3,510.60
August 5 to September 11, 1925	762	375,000	100.0	68	3,841.21
September 11 to October 5, 1925	770	212,000	100.0	38	2,807.00
October 5 to November 4, 1925	480	289,000	100.0	84	2,885.02
November 4 to December 5, 1925	620	282,000	100.0	63	3,041.27
December 5 1925 to January 6, 1926	570	303,053	100.0	74	3,095.22
January 6 to February 3, 1926	610	304,000	100.0	69	3,164.44
February 3 to March 4, 1926	610	297,710	100.0	68	3,428.57
March 4 to April 5, 1926	570	292,000	100.0	67	3,059.17
April 5 to May 5, 1926	600	253,000	100.0	59	2,828.69
May 5 to June 9, 1926	600	204,733	99.9	48	2,492.45

COST OF HEATING, TELEPHONE SERVICE AND ELECTRIC LIGHT SERVICE

The total cost of the coal bill for heating the entire plant for 1925 was $2,938.36. The cubical contents of the pump room is one sixth that of the whole plant and therefore we allocate $490 as the cost of heating the plant.

The telephone service amounts to $92.40, but charging one third of this to the pump plant makes approximately $31 and the electric light cost for lighting the pump plant was $115. This makes the total cost for coal, telephone and lights at $636 for the year or approximately three tenths of a mill per thousand gallons for the above named features of operation. One of the utility men fired the furnace for heating the plant.

TABLE 3

Summary of energy cost

DATE	CURRENT COST PER MILLION FOOT POUNDS	COST OF CURRENT PER 1000 GALLONS	
		Reservoir	Standpipe
January 2 to March 5, 1925	0.0067	0.0188	0.0310
March 5 to April 5, 1925	0.0049	0.0135	0.0227
April 4 to May 6, 1925	0.0046	0.0128	0.0214
May 6 to June 6, 1925	0.0048	0.0134	0.0221
June 6 to July 8, 1925	0.0053	0.0148	0.0245
July 8 to August 5, 1925	0.0061	0.0171	0.0283
August 5 to September 11, 1925	0.0049	0.0137	0.0227
September 11 to October 5, 1925	0.0059	0.0165	0.0261
October 5 to November 4, 1925	0.0053	0.0148	0.0245
November 4 to December 5, 1925	0.0054	0.0151	0.0249
December 5 1925 to January 5, 1926	0.0051	0.0142	0.0236
January 6 to February 3, 1926	0.0052	0.0145	0.0242
January 3 to March 4, 1926	0.0057	0.0159	0.0264
March 4 to April 5, 1926	0.0050	0.0140	0.0231
April 5 to May 5, 1926	0.0054	0.0151	0.0250
May 5 to June 4, 1926	0.0045	0.0121	0.0208
Average	0.0053	0.0148	0.0244

COST OF OIL, WASTE AND INCIDENTAL MISCELLANEOUS SUPPLIES

The plant being practically new the cost of repairs therein has been practically nothing and $16.95 was spent in April for waste, $35 in May for additional floor hardening substance, $7.65 in

May for boots, $39.60 in May for vacuum oil, $48.64 in June for supplies, 75 cents in June for brushes, $13.80 in June for oil, $4.92 in July for charts, $10.80 in August for paint and glass, $42.97 in September for packing, $20.58 in September for oil and brushes, an additional amount of $3.90 in September for oil, $10.82 in December for miscellaneous supplies and $20.74 in December for charts making a total of $277.12. This amount divided by 2,342,126,000 gallons amounts to practically one tenth of one mill per thousand gallons of water pumped.

TABLE 4

Summary of pumping data

DATE	GALLONS OF WATER PUMPED		MILLION FOOT POUNDS WORK DONE	
	Reservoir 334 feet head	Standpipe 555 feet head	Reservoir	Standpipe
January 2 to March 5, 1925	352,763,000	44,107,000	991,000	204,000
March 5 to April 5, 1925	156,160,000	25,170,000	436,000	116,200
April 4 to May 6, 1925	166,693,000	27,676,000	465,000	128,300
May 6 to June 6, 1925	177,328,000	12,218,000	494,000	56,600
June 6 to July 8, 1925	193,620,000	21,492,000	540,000	99,400
July 8 to August 5, 1925	166,355,000	23,455,000	464,000	108,500
August 5 to September 11, 1925	222,485,000	33,782,000	619,002	156,200
September 11 to October 5, 1925	135,800,000	21,605,000	379,000	99,883
October 5 to November 4, 1925	153,399,000	26,417,000	428,000	122,000
November 4 to December 5, 1925	152,427,000	29,982,000	425,500	138,500
December 5 1925 to January 6, 1926	169,427,000	29,765,000	472,000	137,600
January 6 to February 3, 1926	169,465,000	29,003,000	472,000	134,300
February 3 to March 4, 1926	168,050,000	29,215,000	468,000	135,000
March 4 to April 5, 1926	166,614,000	30,314,000	467,500	140,100
April 5 to May 5, 1926	140,350,000	28,721,000	392,000	133,000
May 5 to June 9, 1926	143,735,000	34,675,000	401,000	160,400

Summary of cost per thousand gallons of water pumped

Interest on investment	$0.0014
Depreciation charges	0.0005
Man power cost	0.0055
Energy cost	0.0165
Heat, telephone and electric light	0.0003
Oil, waste and incidental expenses	0.0001
Total	$0.0243

POPULATION DATA

The City of McKeesport supplies the City of McKeesport proper, East McKeesport, Versailles Township, Versailles Borough and Port Vue Borough. The total population for the districts supplied for 1925 according to the post office record in McKeesport is 63,000. During this time 2,342,126,000 gallons were pumped and this means a per capita consumption of 102 gallons per day.

The total cost to own and operate this plant for 1925 was $56,858 or $.90 per capita per year for the high lift pumping operation only.

The pumps are the DeLaval type furnished through the Dravo Doyle Company. The motors were the Westinghouse Electric Manufacturing Company motors. The electrical work was done by the Franklin Electric & Construction Company, through the Pitt Construction Company; the general contract was with the Pitt Construction Company of Pittsburgh. The gate valves, both by-pass and hydraulic, were furnished by the Rensselaer Valve Company.

ELECTRICALLY DRIVEN PUMPING STATIONS AND PEAK LOADS[1]

By J. A. Rue[2]

A peak load period in the electrical industry is known as that portion of the day when the load demand for service by the customers is at the maximum. In this paper we will vary this definition to cover that portion of the day when the demand is materially greater than the average for the twenty-four hours. This usually occurs from 8:00 a.m. until noon and from 1:00 until 4:00 p.m., and again from 7:00 to 8:00 p.m. This general curve will vary between wide limits and is influenced by the season of the year, loads, climate and many other factors.

The ideal load for any power system would be a constant uniform demand of the capacity for which the system was designed. This condition seldom if ever exists, and load curves show the demand to be quite variable.

The modern power plant is designed and equipped with sufficient generating capacity to serve amply its territory at peak load conditions. Therefore, the total station capacity is used only during the peak loads. A part of the equipment is either idle or operating at less than full load the remainder of the day. It has been said that if an electric company can double its power factor, which is the ratio of average demand to maximum, the value of its investment is practically doubled. Since the load factor bears such an important relation to its net earnings, every electric company is desirous of improving its load factor by obtaining all of the off peak business possible.

The electric light and power companies, in order to improve the load factor, can afford to offer special rates for any class of business that will use the service during the off peak hours. Such industries as bakeries, coal mines, drainage districts and some kinds of factories do avail themselves of these special rates.

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[1] Presented before the Illinois Section meeting, March 24, 1926.

[2] Water Engineer, Central Illinois Public Service Company, Mattoon, Ill.

The electric traction companies have partially solved their peak load problem by developing sufficient freight hauling during the off peak hours of the night to balance the passenger traffic during the day time.

A city contemplating the design of a new pumping station or the revamping of an existing station should learn from the power company serving that community what rate could be secured by pumping during off peak hours. This rate might justify a comparatively large investment for elevated storage capacity or other special features of design. The use of electrical energy for pumping water, whether on peak load or off peak load, is not only convenient but economical, for the investment per horse power is low, the maintenance is small and the simplicity of operation is a distinct advantage. These advantages have been recognized by many water companies and municipalities throughout the state which have electrified their pumping stations during the last five years.

While it is not possible for all water stations to operate their pumping equipment during off peak hours, there are, however, a large number that could satisfactorily operate in this manner. The water stations that could not wholly use off peak service could in a great many instances do part of the pumping during the off peak hours.

A great many small towns of 2000 population or less have an elevated storage of sufficient capacity to last through the electric peak load period. Such towns could probably reduce their power bills by operating their plants at night instead of in the day-time. There are also towns so blessed by nature as to have a natural elevated storage and these can do all of their pumping on the off peak period.

There are many cities which have large surface storage sufficient to last two or three days. The reservoirs are either of concrete or earth and are replenished by pumping from deep wells, rivers, or other sources of supply. A town having this arrangement can fill the reservoir during off peak hours and do the necessary service pumping during the peak hours, and in this way effect a considerable saving in operation.

The determination of the amount of money that can be spent on elevated tanks and on surface storage of sufficient capacity to permit operation with cheap off peak power is a problem of economics. The water plant engineer can readily calculate the savings to be secured by lower rates from pumping during the off peak hours as compared with the interest on the investment necessary to install elevated tanks or to build surface storage. It would be surprising how large an amount can be spent in this connection with no increase in the total operating cost. The Illinois Fire Inspection Bureau will give a better insurance rating to towns having a large elevated storage than to towns with small storage.

Rapid strides have been made in the perfection of electric metering equipment and it is now possible to install a dual meter set with time switch so that it will meter the power used during the peak period on one meter and the power used on the off peak period on the other meter. By this method different rates can be charged for the power used over the two different load periods.

With this arrangement the operation of the water plant could be such that the greatest saving could be effected by operating as many hours as is possible during the off peak period.

Operation with this dual metering equipment has already been used by various classes of power users. In my opinion, there is no reason why the water plants cannot take full advantage of such operation.

In conclusion, it is recommended that every manager of a water plant investigate the possibility of operating a part or all of their pumps on off peak load periods.

COST ACCOUNTING FOR PIPE LAYING JOBS[1]

By Homer V. Knouse[2]

Cost accounting as an element of utility operation or construction is of universal appeal. The size of the property or the extent of the operation does not greatly affect the interest, for in any case the balance sheet is the principal index of the success of the enterprise. The operator of a small property must conserve his resources and scrutinize his expenditures quite as carefully as the department head or executive of a plant supplying many thousands. Failure to watch carefully all expenditures and neglect in the study of costs in terms of units of output or construction will ultimately result in embarrassment or in many cases failure.

Cost accounting may have several objectives, and each will require a somewhat different treatment. If it is for the purpose only of maintaining a perpetual inventory of the plant, much less detail will be necessary than if it is for the guidance of the estimating department. The power plant operator will care less about the total tons of coal burned than in the coal cost per thousand gallons of water pumped or kilowatt hour of power delivered to the bus bars. The ideal system is one, of course, which will entail the minimum amount of labor in its development and use, and which will contain elements from which each class may obtain the information they desire. Much time and study has been given to the subject by executives and accountants, and in the larger plants the entire time of departments of considerable size is required to collect necessary data and put it in shape to be of use by each of the interested persons in the organization.

While the plan described herein contains all the elements which could be desired by any department, whether it is the accounting, the engineering or operating, it has been developed to serve, in addition to the above, a part of the organization which is not generally considered when systems are developed, namely, the gang foreman. The foreman should be given consideration, for the economical handling of construction work rests largely on his shoulders. By placing in his hands such data as will enable him to analyze his methods of doing work it is inevitable that greater efficiency will result. The foreman is thus raised from the status of a "herder" of common labor to that of a man who has responsible charge of a small business, and the proper type of foreman is bound to respond to this responsibility and increase his own efficiency as well as build up a better gang of men under him.

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[1] Presented before the Iowa Section meeting, November 4, 1926.

[2] Construction Engineer, Metropolitan Utilities District, Omaha, Nebr.

This paper will describe the plan used to obtain costs of laying water and gas pipe and variations will suggest themselves to adapt it to other classes of work or to particular local conditions. Special attention has been given to the element of time, so that as complete data as possible are available to the foreman within a day or two after the completion of the job, in order that he may have all the circumstances fresh in his mind when checking his costs.

Data for labor costs are reported by the foreman on his daily time sheet to the timekeeper. Labor is subdivided as follows:

Foreman and miscellaneous
Excavating
Pipe laying, including jointing
Refilling, including flushing or tamping
Cutting paving
Repaving

From these data the Timekeeper's Department posts totals to a labor recap sheet daily, and immediately upon the completion of the job the totals and unit costs are figured and a summary forwarded to the foreman. No attempt is made on this preliminary report to include material costs, since the compilation of material costs requires more time, and the amount of material used is largely out of the foreman's hands.

All material is delivered by the storekeeper on orders of the foreman and quantities drawn are checked against the quantities as used in the job. A field clerk makes a report of all material used, as well as of the location of the completed line, location of valves, hydrants, special castings, and structures of other utilities which are encountered during the progress of the work. Notes are made as to the size of paving cuts, character of the weather, and any other element which would affect the cost of the work. The completed report is a complete record of the job and is used by all departments for their particular records. The Accounting Department is interested in the total cost to be added to the plant values, and notes the additional hydrants that are to be billed to the city; the Engineering Department posts the data on the necessary maps; the Tax Department uses the data for extending the assessments against abutting property. Data as to hydrant pressures, dead ends, etc. are posted on the proper records and the report finally is filed as a permanent record. A summary of the total cost is then forwarded to the foreman who had charge of the work for his information and guidance.

A marked increase in efficiency and decrease in unit costs has been noted since this method of aiding the foreman has been in effect. There is a friendly rivalry between gangs to get low costs and large footage of pipe laid, and any element out of their own control which affects costs is quickly brought to the attention of the General Foreman for adjustment. As an example of this kind, a Foreman reported that he could not keep down his costs of refilling ditch due to the large amount of trimming or cleaning up when a particular backfiller was used on the job. A study of the operation of this backfiller disclosed that it was making about 40 per cent more footage than another similar machine, but that this gain was in fact at the expense of careful cleaning up. The unit costs of this machine were of course less than the other machine, but when the cost of additional labor was added it was clearly demonstrated that the operator on the "slow" machine was the most efficient.

Carelessness in the handling of material by truck drivers which caused breakage produced an increased labor cost on the job and reports were soon available from the Foreman which located the trouble. Defective castings and poor quality of any material are more carefully checked in order that there will be no additional or unnecessary labor to complete the job.

THE WATER WORKS PLANT OF BUTTE, MONTANA[1]

By Eugene Carroll[2]

In the following paper the writer gives a short description of the water works plant of the Butte Water Company. Coming to Butte in the fall of 1891, to superintend the construction of a masonry dam on Basin Creek, the writer was soon after made superintendent, and ever since has been in charge of the design, construction and operation of this plant.

At first thought the plant impresses one as being complicated and of entirely too large a capacity for a community of 65,000 people. When it is considered, however, that the mining properties in the vicinity of Butte, large consumers of water, are dependent entirely on this plant, and when it is realized that in case of fire under ground, an enormous amount of water is required quickly, the reason for building a plant of such large capacity is explained. The apparently complicated design, requiring five separate distribution systems, is caused by the contour of the territory served, and its high elevation above sea level.

While always avoiding extravagance in the construction of the plant, economy at the expense of sound engineering principle has never been the practice. Every part is constructed of the best material obtainable and extreme care has been used in its erection. To this may be attributed the fact that no costly mistakes have developed in the physical plant, and our operation costs have always been relatively low. If the plant were to be rebuilt at the present time, the writer knows of no material changes which he would consider advisable, other than improved machinery.

HISTORICAL

During the year 1891, A. S. Biglow, President of the Boston and Montana Mining Company and Associates organized the Butte City Water Company. They purchased from the late Senator W. A. Clark and Associates, the water works plant of Butte, consisting of nineteen miles of distribution mains, having 1750 consumers, serving a population of about 11,000.

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[1] Presented before the Montana Section meeting, April 17, 1926.

[2] Vice President and Manager, Butte Water Co., Butte, Montana.

The construction of the new plant was started October 1, 1891 and in the spring of 1892 work was started on the construction of the Basin Creek Dam. Owing to the rapid growth of the community and mining enterprises in the vicinity, coupled with political trouble with the city authorities, and algae trouble with the water supply, the Company soon found itself in financial difficulties, conditions making it impossible to finance needed improvements and extensions. In 1898 the Company was placed in the hands of a receiver and reorganized, the new Company being known as the Butte Water Company, which procured $1,000,000 additional capital and proceeded with the construction of the additional supply required from the Big Hole River. Since that time matters have been moving smoothly, the Company gradually paying off its indebtedness, and living in the hope at some future time of giving some return to the original promoters and stockholders. The Butte Water Company is incorporated under the laws of New Jersey, with a capital stock of $5,000,000, three million of which has been issued. There is no bonded indebtedness.

GENERAL DESCRIPTION

The Butte water works system supplies water to what is known as the Butte Mining District, which includes the incorporated cities of Butte and Walkerville, and communities adjacent, known as Centerville, Meaderville, East Butte and South Butte. The district extends over an area of about fifteen square miles, and varies in elevation from 5400 feet to 6368 feet above sea level. The mines of the Anaconda and other mining companies are within the district.

The problem of supplying with water, a large community located at a high altitude, practically on the Continental Divide, presents a most interesting problem, more complicated from the fact that the only stream of any consequence within the vicinity, Silver Bow Creek, is unfit for human consumption because of its being used for general sewage of the mines and inhabitants. The streams above these industries are small, and notwithstanding the development of two of them, made available by large storage reservoirs, the annual gravity water supply amounts to only about 6,000,000 gallons average per day. For this reason it was necessary to develop a supply from the

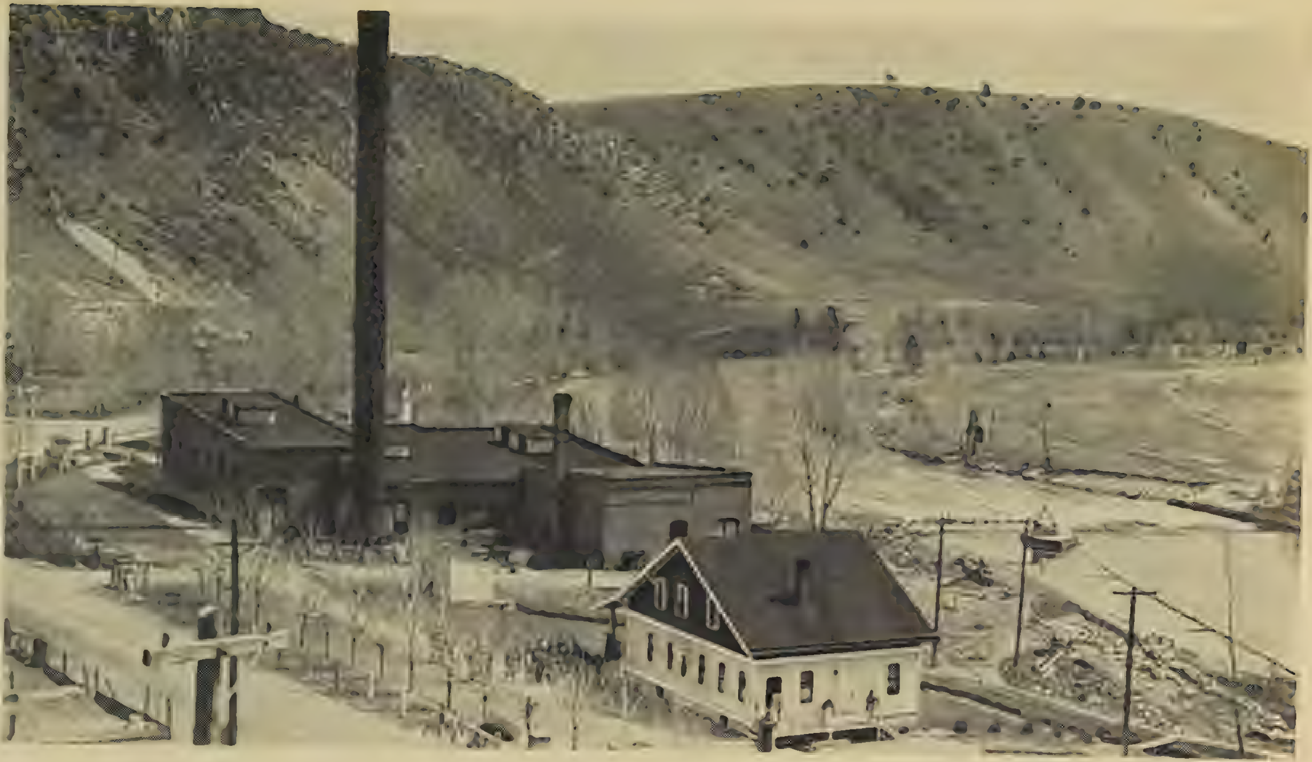

FIG. 1. BIG HOLE PUMPING PLANT, BUTTE WATER COMPANY

Installed 1899; electrified 1913; total pumping capacity 15 million gallons daily. Supply from Big Hole River. Elevation 5402 feet above sea level

Big Hole River, on the opposite side of the Continental Divide, pumping the water across the Divide, a distance of about 27 miles. Butte is located on the side of the mountain within a horsehoe in the main Continental Divide, and the district is drained by Silver Bow Creek, one of the head waters of the Columbia River, which flows through a box canyon to the West.

The entire system is comprised of two pumping stations, five storage reservoirs with a total capacity of over 700,000,000 gallons, 85 miles of transmission mains, ranging in size from 12 to 26 inches in diameter, five distributing reservoirs with a total capacity of about 18,000,000 gallons with 150 miles of distributing mains ranging from 12 to 20 inches in diameter. The pumping stations are located at the Big Hole River and West Side. The storage reservoirs are located on Basin Creek, and on the head waters of Silver Bow Creek. The South Fork Reservoir located on Divide Creek is both storage and distributing.

The distributing system is divided into 5 divisions as follows: The *Moulton System* which supplies the inhabitants of Walkerville to the North and receives its water from the Moulton Reservoir; the *High Service System* which supplies the community of Centerville and the adjacent mining properties, receiving its water from the Moulton Reservoir, augmented by the West Side Pumping Station; the *Middle System* which extends from the north limits of the City of Butte to elevation 5700 feet on the south, receiving its water from the West Side Reservoir, which is supplied from the Big Hole System; the *Lower System* extending from elevation 5700 feet to the south limits of the City of Butte including the community of Meaderville and the mining properties in that vicinity, receiving its water from Basin Creek Reservoir augmented by the Big Hole System; the *South Side System* including all of the community south of the south limits of the City of Butte, receiving its water from the South Side Reservoir which is supplied from the Basin Creek Reservoir.

All systems are connected together, divided by valves, so that in case of necessity it is possible to augment any district from the system above.

RESERVOIRS

Basin Creek Dam No. 1, located on Basin Creek, 13 miles south of the city limits, was started early in the Spring of 1892. It is of monolithic construction, consisting of large blocks of granite with

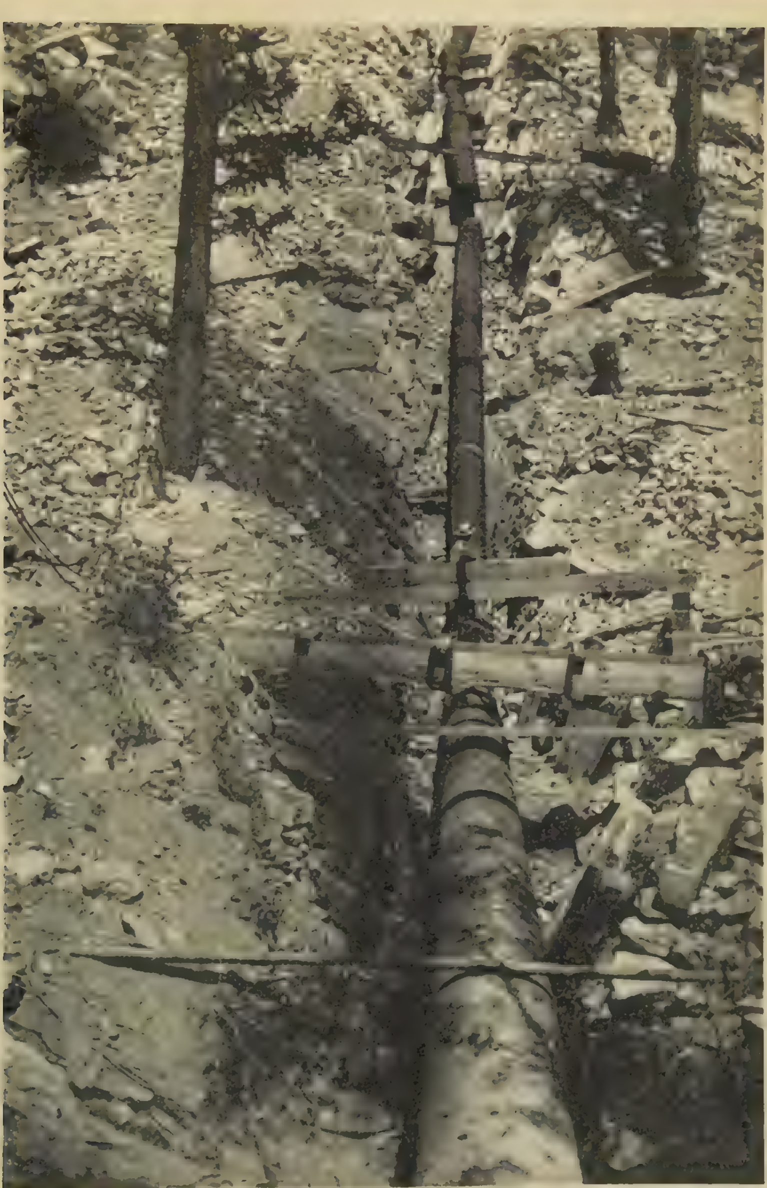

FIG. 2. LAYING 26-INCH STEEL PIPE, WELDED JOINTS, THROUGH SOLID ROCK IN THE ROCKY MOUNTAINS

the interstices filled with concrete. The water face is finished with cut stone. This construction extends to elevation 5860 feet and, in 1913, 13 additional feet were added of reënforced concrete, making the elevation of the coping 5873 feet above sea level. The dam is built at the junction of Bear Creek with Basin Creek and has a length of crest of 270 feet, built with a gravity section on a curve of about 350 feet radius. The crest is 73 feet above the creek bed and 101 feet above the lowest point of the foundation. It contains about 11,000 cubic yards of masonry, and 3600 cubic yards of concrete. Eight thousand pounds of steel were used in reënforcement of the last 13 feet built of concrete. There are three 20 inch cast iron pipes through the bottom of the dam, two being used as supply lines, the other as a blowoff pipe, all regulated by valves located in a valve house at the lower toe of the dam. The water is received in the pipes through elbows just inside of the water face, on which valve seats are placed to receive screens or covers lowered and regulated by a derrick on top of the dam. The reservoir formed by this dam has a capacity of 370,000,000 gallons.

Basin Creek Dam No. 2, located about a mile and a quarter above No. 1 on Basin Creek was originally constructed in 1898 as a rock filled crib dam, and reconstructed in 1907 by placing a concrete core wall on the vertical water face of the dam with an earth fill. It is 40 feet high, and has a top width of 16 feet with a length of crest of 320 feet. The reservoir formed has a storage capacity of 60,000,000 gallons. The upstream face of earth has a slope of 1½ to 1 and is paved with hand-laid rock. There are 46,000 lineal feet of logs, 9934 cubic yards of rock, and earth filling, 8511 cubic yards of earth face, and 985 square yards of rock paving. A 12-inch pipe regulated by a valve at the lower toe of the dam, turns the water from the reservoir into the creek below, through which it flows into Basin Reservoir No. 1. In addition to storage this reservoir is used during the spring months as a settling basin.

South Fork Dam is built on the South Fork of Divide Creek, a stream heading on the Continental Divide and flowing into the Big Hole River. It is an earth dam with a concrete core wall, having a maximum height of 33 feet with a top width of 16 feet and a length of crest of 315 feet. The upstream face is on a 2 to 1 slope paved with rock, handlaid, with a down stream slope of 2 to 1. This dam was constructed in 1899 and forms a reservoir having a capacity of 13,472,000 gallons. In addition to storing the waters of Divide

Creek, it holds the water pumped from the Big Hole Station. This dam consists of 23,750 cubic yards of earth fill, 1475 cubic yards of concrete, 1967 square yards of paving, with a concrete spillway containing 75 cubic yards. The water runs by gravity from the South Forest Reservoir to the Westside distributing reservoir in town.

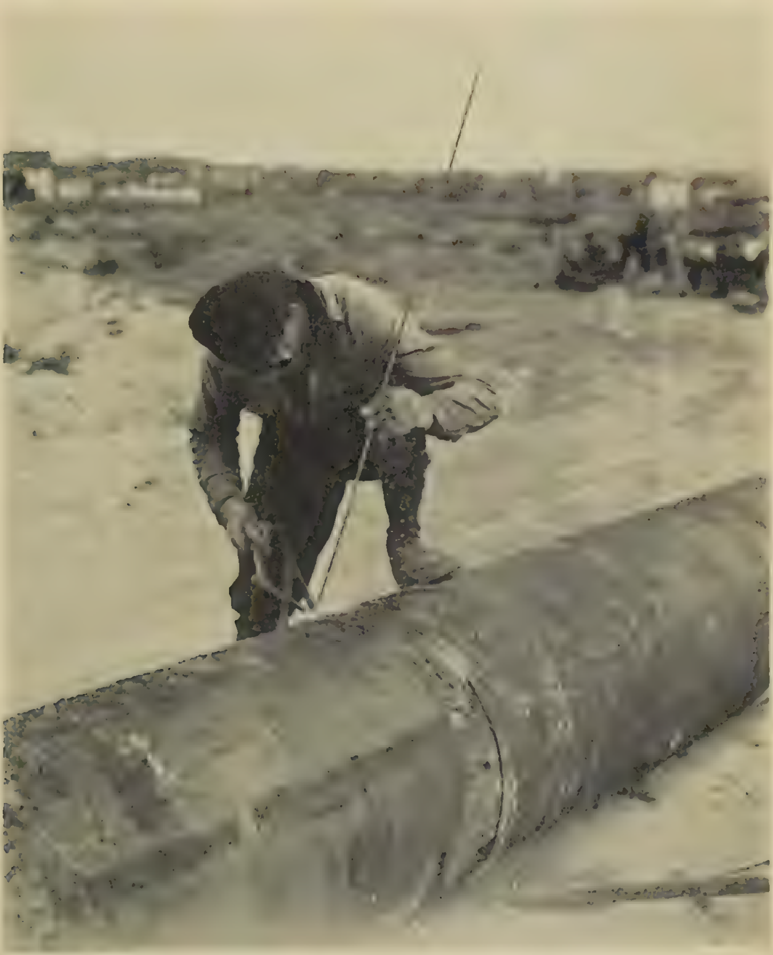

FIG. 3. WELDING A JOINT ON 24-INCH STEEL PIPE AT BUTTE, MONTANA

Moulton Dam No. 1. This dam is located on the head waters of

Silver Bow Creek about 7 miles north of the city limits of Butte. It is an earth dam with a concrete core wall, having a height of 60 feet with a top width of 15 feet and a length of crest of 500 feet. It was constructed in 1907, the upstream face having a slope of 2 to 1, paved with hand-laid rip rap, with a slope of 2 to 1 on the downstream face. A 24-inch outlet pipe, of cast iron embedded in concrete, turns the water from the reservoir into the creek below, regulated by a valve located in a valve chamber just inside of the upper toe of the dam. There is also an 8-inch cast iron blowoff pipe. The top of the dam is elevation 6756 feet, 60 feet above the creek bed, the bottom of the core wall extends 28 feet below the creek bed. It forms a reservoir having a capacity of 261,000,000 gallons and has a large concrete overflow. It contains 83,866 cubic yards of embankment, 4429 cubic yards of concrete and 5658 square yards of paving.

Distributing reservoirs. There are five distributing reservoirs of various construction, all of concrete. Two small ones built square with concrete walls below the surface, and covered, for the Moulton System; one concrete triangular reservoir for the high service system; one of concrete for the middle system; one circular concrete reservoir for the Southside system.

PUMP STATIONS

The Big Hole Pump Station, located on the Big Hole River, contains two horizontal triple expansion Nordberg pumps, and one Worthington five stage turbine, all driven by electric motors. The Nordberg pumps were originally installed to be driven by steam, but in 1913 were converted to electric drive. Pump No. 1 was converted by replacing the fly wheels with herring-bone gear driven by an electric motor. Pump No. 2 was electrified by disconnecting the steam end and installing at the other end an electric motor, driving two twenty-four feet wheels with rope drive. The steam connection of No. 2 was not disturbed and in a short time can be reconnected in case of emergency. Pump No. 1 has a capacity of 5,000,000, pump No. 2, 4,000,000 and pump No. 3 which is a 12-inch, five-stage horizontal turbine pump, has a capacity of 6,000,000 gallons per day. Pumps Nos. 1 and 2 are driven by induction motors, of 800 horsepower each. Pump No. 3 is driven by an induction motor of 1300 horsepower.

A small rock filled crib dam is built in the river to form an intake reservoir, from which the water enters a concrete intake chamber

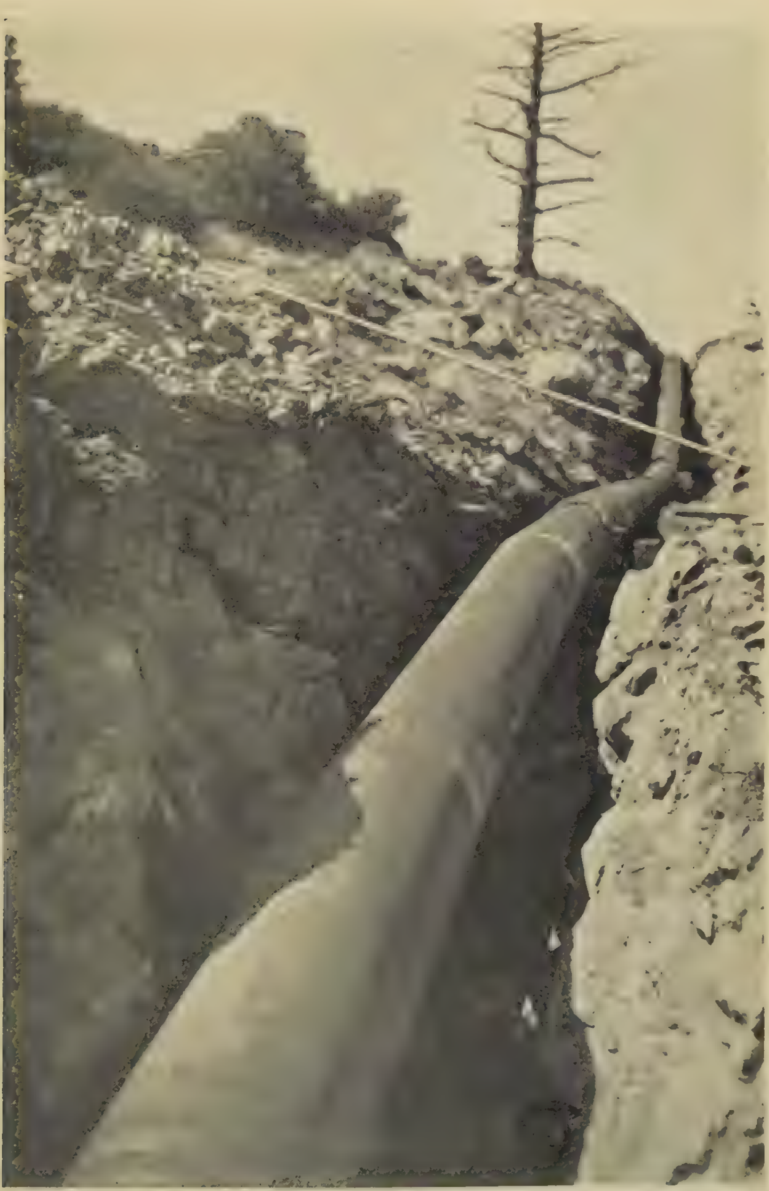

FIG. 4. A REVERSE VERTICAL CURVE THROUGH SOLID ROCK; 26-INCH STEEL PIPE, WELDED JOINTS

connected to a suction well near the pump station, by two concrete conduits. The suction pipes of the pumps, protected by foot valves, receive their water from the suction well, the water being screened at both the intake chamber and where it enters the suction well. A Wallace and Tiernan plant chlorinates the water in the suction well, using from 1 to 3 pounds per million gallons of water pumped, depending on the bacterial condition of the raw water.

The elevation of the engine room floor is 5402 feet above sea level and the water is pumped from this station to elevation 6152 feet, where it enters the South Fork Reservoir. The friction loss in the pipe lines between the Big Hole Station and the South Fork Reservoir requires the operation of the pumps under a pressure of from 360 to 375 pounds per square inch.

As a reserve equipment, to be used in case of emergency, two 300-horsepower Stirling water tube boilers are kept in condition for the steam end of pump No. 2. A temporary triple expansion steam pump was installed in 1899, and in 1901 pump No. 1 was installed, followed in 1907 by pump No. 2, and in 1917 by pump No. 3. Pump No. 2 was electrified in 1907 and pump No. 1 in 1913.

The pump station is of ordinary brick construction on concrete foundations, with concrete floors, and is equipped with traveling cranes, and repair shop. Three modern houses take care of the employes, the grounds being beautified and maintained as a public park.

The West Side Pumping Station, which supplies the deficiency in the high service system is located at the east end of the Westside Reservoir, and contains two Nordberg rope driven pumping engines, horizontal duplex type, driven by fourteen feet rope wheels mounted on crank shaft. Each pump is driven by a three phase 150 horsepower induction motor, 450 r.p.m., pumping against a pressure of 150 pounds. The suction pipes from the pumps connect directly to the West Side Reservoir and deliver the water through the high service system to the high service reservoir at elevation 6255 feet, the elevation of the pump house floor being 5949 feet. The capacity of the electric pumps in this station is 2,000,000 gallons in twenty-four hours for each pump.

A triple expansion duplex Worthington pump operated by two-eighty horsepower horizontal tubular boilers is kept in reserve at this station. Originally the equipment of this station was steam, installed in 1899, the new electric pumps being installed in 1907 and 1910 respectively.

The building is of brick construction on concrete foundations with concrete floors, and equipped with a travelling crane. The grounds around the westside reservoir and pumping station are beautified and maintained by the Company as a public park. A modern brick residence is located near the pump station for the watchman and a large warehouse is maintained on the grounds.

INFLUENT PIPE LINES

Connecting Basin Creek Reservoir with the city system are two influent pipe lines constructed in 1892 and 1914. They are parallel, the older one consisting of 49,750 lineal feet of 24-inch banded Redwood continuous stave pipe, the second line consisting of 38,100 lineal feet of banded continuous stave fir pipe, and 12,930 lineal feet of 24-inch Matheson joint steel pipe.

Connecting the Big Hole Pump with the Westside Reservoir are two influent pipe lines. The first was constructed in 1899 and 1900, and has a length of 27.1 miles, from the Big Hole Pumping Station to the West Side Reservoir, with a capacity of 8,000,000 gallons per day. The second line built in 1920 practically parallels the older line with the same capacity. The older line known as No. 1 consists of 3055 feet of 26-inch riveted steel pipe, 43,502 feet of 26-inch wooden pipe to the South Fork Reservoir, thence 97,912 feet of 24-inch wood and 26 inch steel pipe to the West Side distributing reservoir in Butte. Banded continuous stage redwood pipe is used for heads up to 250 feet and riveted steel for higher heads. Pipe line No. 2 has a total length of 139,958 feet and consists of 3525 feet of 26-inch and 22,211 feet of 24-inch lap welded steel pipe, and 43,422 feet of 26-inch, and 70,800 feet of 24-inch continuous stave redwood pipe. The wood pipe was used for all heads under 300 feet. On both these lines 26-inch pipe was used between the Big Hole Pumping Station and South Fork Reservoir and, 24-inch between South Fork and Westside Reservoir.

On each line between South Fork and West Side Reservoirs four regulating chambers are installed to reduce the pressure limits for low head wooden pipe, thereby making a large saving in first cost. Each chamber contains a valve operated by a float in the chamber on the outlet side. Each is provided with an overflow, which, in case the valve fails to work, will prevent a pressure on the pipe line below.

On No. 2, lap welded steel pipe, furnished by the National Tube

Company with beveled ends, was used. It varies in thickness to conform to the pressure and was delivered in varying lengths, averaging 16.83 feet. The oxyacetylene process was used to weld circumferential joints. It is interesting to note that after five years of operation it has proven entirely satisfactory. Welded joints were adopted along the lines for economy, both in construction and delivery of material, the cost being much less than any other available joint. Weir chambers are installed on each line, where it enters the Westside Reservoir.

Connecting the Moulton Reservoir with the distributing reservoirs north of Walkerville is an influent pipe line of 12-inch wood pipe and 16-inch steel pipe, 22,900 feet long. Fifty-seven hundred feet of 12-inch wood pipe connects the reservoir to a sand and screen chamber from which point it is carried through 17,200 feet of 16-inch Matheson joint steel pipe, connecting to the distributing reservoirs. The screen chamber is also connected to the creek, and at certain seasons of the year considerable water is secured in addition to the water from the Reservoir. At the lower end of this line a weir chamber is installed before entering the distributing reservoirs, and a Wallace and Tiernan installation chlorinates the water.

Connecting the waters of Fish Creek with the Basin Creek System is a 14-inch wire wound fir pipe, diverting the head waters of Fish Creek across the Continental Divide, emptying into the water shed of Basin Creek. A concrete weir chamber is installed on the summit, from which the water flows through natural channels to Basin Creek. This pipe line takes the water from Fish Creek at an elevation of 8493 feet, crossing a deep valley with a maximum pressure of three hundred feet and discharging into Basin Creek water shed, at elevation 8400 feet. It has a capacity of 3,231,000 gallons per day.

At a point about 2 miles south and west of the City limits a 12-inch pipe connects the two Big Hole lines with the Basin Creek System. This cross connection is made to enable water to be delivered from the Big Hole System to the lower Basin Creek System, and South Side System, without passing through the Distribution System.

CITY DISTRIBUTION SYSTEM

Kalamein steel pipe is used exclusively throughout the distribution system, and being flexible, meets very satisfactorily the unusual conditions imposed by the continual movement of the ground caused by mining operations. The movement of the surface causes telescoping and pulling of joints, failure being indicated by small leaks, rather than sudden breakage, as would be the case with cast iron pipe. In some instances joints have been telescoped as much as 11 inches.

In parts of the system the ground is impregnated with sulphuric acid and considerable trouble has been experienced by the water company from this cause. Various experiments have been made from time to time with a view of protecting the pipe in these districts, and we have found the only satisfactory protection is embedding it in concrete through the acid soil. Considerable trouble from electrolysis was experienced until the Street railway improved the method of overhead return and welded the greater part of the rail joints. The oldest pipe now in use was laid in 1886, and a considerable amount was laid in 1891, extensions having been made every year since.

Mains are laid with a cover of 6 feet, the average frost penetration being 5 feet, with a maximum of seven feet. Recording pressure gauges are maintained at the Galena Street Shop, at an elevation of 5699 feet and on the West side and Upper Basin Creek Services. The system is so divided that a pressure of from 105 to 117 pounds is carried in the congested district with a minimum of 60 pounds in the outlying residential districts at extreme elevations.

The South Side System is located between elevations 5425 and 5510 feet, and is almost entirely residential. A twenty inch main extends east from the south side Reservoir along the southern boundary of the area served, with 12-inch mains branching to the north.

The Lower System receives its water from the Basin Creek Reservoir and supplies residential and minor mercantile districts, an important warehouse section and mining district. The elevations range from 5510 to 5710 feet. Two 20-inch supply mains from Basin Creek transmission mains extend to the southern limit of the service continuing in two parallel lines on each side, of 18- and 16-inch diameter, which are cross connected at various points by 12-inch mains.

The Middle System supplies the main business section and high class residential district. The supply is by gravity from the West Side Reservoir, elevations ranging from 5600 to 5910 feet. The district is supplied through a 16- and a 14-inch main, running from the Reservoir around each end of the district, grid ironed with 12- and 10-inch mains.

The High Service System supplies several small mercantile sections and residential districts north of Butte, and mining properties. This system is supplied from the Westside pump, which delivers water through the system to the high service reservoir. A part of the supply for this system is by gravity from the Moulton Distributing Reservoirs. Mains range from 6- to 14-inch.

The Moulton System supplies a section at a higher altitude than the high service reservoir, principally residential. It receives its water from the Moulton distributing reservoirs through two 12 inch mains, extending through the area.

In the congested districts the mains are mostly 10- and 12-inch gridirons, but owing to the topography of the country there are a number of dead ends in the outlying districts, though not excessive. Valves are liberally distributed throughout the system and fire hydrants are maintained to furnish fire protection to the community and the mining companies, without the use of steam fire engines. No mains less than 6-inch is used to supply the fire hydrants and the standard maintained for fire protection is very high, as evidenced by reports of the National Board of Fire Underwriters. Frequent flow tests by the Underwriters indicate that the distribution system is ample in all parts of the district.

Daily record of the consumption is measured by weirs and Venturi meters on the supply conduits, readings being taken twice daily. The maximum month was January, 1917, when the daily consumption averaged 13,600,000 gallons, but the average annual daily consumption runs between 9,000,000 and 11,000,000 gallons. The records show that the heaviest consumption is during dry periods in midsummer, and during protracted periods of cold weather, when taps are left open to prevent freezing. Over 20 per cent of the entire consumption is used in the mines through metered services, though only 5.7 per cent of the total services are metered. The distribution system consists of 792,639 lineal feet of pipe, varying from 2 to 20 inches in diameter, 2-inch being used only for small residential gridirons, the minimum size of mains for fire protection being 6-inch. There are 765 fire hydrants in commission, 113 of which are paid for by private parties, the balance being under contract to the City of Butte, Silver Bow County and the City of Walkerville. On January 1, 1926 there was a total of 10,763 consumers, 861 of which were metered. It is our universal custom to meter all large consumers, private residences being unmetered, unless requested by the consumer. Meters are owned and installed by the company, without expense to the consumer, with a minimum charge for different classes of service. House connections are made by licensed plumbers at the expense of the consumer, the Company furnishing the Corporation Cock and making the tap free. Standard curb cocks are sold at cost by the company to plumbers. The company maintains the main lines that pass the mining properties, but all extensions are paid for by the mining companies. All service pipes to private consumers must be laid in a ditch at least 6½ feet deep, before connection will be made and water turned on. If it is necessary to prepare a receptical for a meter, the consumer pays the actual cost of its construction. The municipalities served pay for fire protection at a stipulated amount per hydrant and also pay for water used in sprinkling the streets. Flushing sewers and public building supply are furnished without cost to the city.

ORGANIZATION

Under the general manager there are four departments, with the department-head, directly responsible to the manager. These are as follows:

The Maintenance and Repair Department under a superintendent who has entire charge of the physical plant, and supervision over all employees in the operation and maintenance of the system, except the office employees.

The Office Department in charge of a chief clerk who is responsible for the financial operations of the Company.

The Inspection Department under a chief inspector who is responsible for rates, and supervision over the consumers.

The Engineering Department under the charge of a chief engineer who has charge and supervision of all new construction and extensive replacement work.

Complete records are kept of the physical plant and daily reports made to the manager. The engineering department records all physical changes and keeps the general and detailed maps up to date. The inspection department keeps complete record of the rates and conditions of all house connections, keeping the records up to date by a system of continual house to house inspection, working in conjunction with the office force.

Courteous treatment of the public is demanded from all employees who are impressed with the belief that no one is so small, that the company can afford to make an enemy of him. The continual effort of every employee is to get and retain the good will of the public, and all we ask from them is fair treatment.

CONCLUSION

In a paper of this character it is impossible to discuss any details. Each division of a water plant such as this could be made the subject of a complete article, containing many interesting details to engineers and water works men.

From 1891 until 1920 more or less construction and extension work was done every year until every part of the plant was in duplicate, and ample reserve provided for emergencies and future growth. If time permitted many interesting points could be elaborated, the principal of which may be summarised as follows:

The successful use of copper sulphate in the treatment of the water in the various reservoirs to eliminate taste and smell from vegetable algae.

The successful use of electricity for pumping water under high pressure and relative advantage of the turbine pump over the rope drive, or any other reciprocating pump, when first cost is taken into consideration.

The advisability of the use of wooden pipe on account of its low first cost and low maintenance cost. That wooden pipe properly constructed has long life is demonstrated in our Basin Creek Line No. 1, which is still in splendid condition after being in continual service for thirty-four years.

The use of regulating chambers on the Big Hole influent pipe lines which resulted in enormous saving in first cost, and which have proved entirely satisfactory.

The use of lap welded steel pipe with welded joints installed in 1920 on Big Hole Line No. 2, which has proven eminently satisfactory, both in first cost and in maintenance.

The exclusive use of Matheson Joint welded steel pipe in our city system which has proved eminently satisfactory not only in first cost, but in cost of maintenance. The fact that some of this pipe has been in continuous operation for forty years indicates long life for that class of material.

In conclusion, from past experience in this and other water works construction, the writer believes that many of the difficulties and grief experienced by water works officials in the operation of a water works plant, can be eliminated by the use of good material and careful attention to the details of construction. Often low first cost is forced on engineers against their better judgment, and invariably results in losses in maintenance and repairs after construction. It is a pleasure to state that in the construction of this plant, while often in financial straits, nothing was attempted unless the funds available were sufficient to procure the very best in workmanship and material, and of ample size. It is better to delay than to use cheap substitutes. The splendid condition of the plant today, parts of which have been in operation for over forty years, is a credit to the efficient corps of employees.

THE SIGNIFICANCE OF NITROGEN DETERMINATIONS IN SANITARY ANALYSIS[1]

By S. L. Neave[2] and A. M. Buswell[3]

Free ammonia is perhaps the oldest of the nitrogen-methods in sanitary analysis. As an end product in the bacterial metabolism of nitrogenous compounds, ammonia determinations may signify remote pollution of a water by organic matter. In sewage, similarly, free ammonia indicates the extent to which bacterial hydrolysis has proceeded. The difficulties in accurately determining ammonia by distillation have been appreciated. Mallet (1) in 1881 pointed out that: "In the case of waters containing urea, and also other amidated bodies such as leucine and tyrosine occurring among the products of putrefactive decay, some ammonia is so easily formed from these substances by boiling with sodium carbonate, or even without this addition, that it is impossible to distinguish sharply between pre-existing 'free' ammonia (of ammonium salts), and that formed by the action of alkaline permanganate, the so-called "albuminoid ammonia." Phelps (2), in a paper before the Laboratory Section of the American Public Health Association (1903), gave experimental data on the "free ammonia" of such substances as urea, gelatine, casein, egg albumin and peptone, showing that in all cases a small per cent of the nitrogen was liberated during distillation. Since the presence of sodium carbonate seems to promote these hydrolyses, various attempts (3) have been made to substitute a milder alkali, such as MgO, in its stead.

Direct nesslerization following copper sulphate clarification of course obviates this decomposition, but for the most accurate work nesslerization is an uncertain procedure when dealing with a mixture like sewage. Sulfur compounds and aldehydes produce too dark a color; protective colloids like proteins and peptones, which are not removed by the $CuSO_4$ treatment, inhibit color formation; many salts cause troublesome turbidities; and the small amount of amine nitrogen which is present even in fresh sewages is not included in the nessler color and consequently escapes determination. The present writers have successfully used aspiration of the ammonia into standard acid to avoid the defects of both the distillation and the direct nesslerization methods.

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[1] Presented before the Water Purification Division, Buffalo Convention, June 9, 1926.

[2] Chief, State Water Survey Division, Urbana, Ill.

[3] State Water Survey Division, Urbana, Ill.

The albuminoid ammonia determination was proposed by Wanklyn, Chapman and Smith (4) in 1867 as a measure of the unhydrolyzed, or only partially hydrolyzed, nitrogenous matter in a water sample. The digestion with alkaline potassium permanganate was thought at first to completely destroy such substances with a quantitative liberation of ammonia. Frankland and Armstrong (5) at that time were advocating their combustion method for carbon and the rivalry between the two methods brought to light some interesting defects in each. The great weakness of combustion processes, of course, is the preparation of a dry residue without loss of volatile components. It was carefully tested out by Mallet (1) in a long series of analyses and the precautions found to be necessary for reasonable accuracy exclude it from the class of routine methods. Clark and Adams (6), however, used the combustion process with some success in studying the carbon content of sewage.

The incomplete hydrolysis of urea during the permanganate digestion was recognized by Wanklyn (7), but naïvely avoided by the statement that while pure urea was only partially decomposed, the impure urea of a sewage-polluted water showed no such resistance to hydrolysis. It was soon recognized, however, that the albuminoid ammonia nitrogen represented only a fraction of the total and various multiples of it have been adopted from time to time as measures of total nitrogen. Using a long series of known nitrogenous substances, Mallet (1) found the per cent of nitrogen liberated to vary from 0 to 95, with an average of 53. Even exhaustive treatment with alkaline potassium permanganate, in some cases requiring several days, did not give complete recovery of nitrogen. He concludes: "The value of the results by this process (alb. NH_3) depend more upon watching the progress and rate of evolution of the ammonia than upon determining its total amount." Phelps (2) also, in the report mentioned above, found wide variation in the recovery of ammonia from nitrogenous substances. In a series of sewage analyses, an average of 34.8 per cent of the total nitrogen was liberated, though individual samples varied from 15.2 to 54.8 per cent. The formula of Fuller,

$$\text{Total N} = \frac{12 \times \text{alb.NH}_3}{\text{Free NH}_3}$$

was thus shown to be in error in some cases by 25 per cent for "water," but for sewage the error would be much greater.

The Kjeldahl process for total organic nitrogen requires no discussion. It is subject merely to the error in the free ammonia when determined on the residue from the ammonia distillation. It would seem more desirable to determine total nitrogen by the Kjeldahl method and subtract free ammonia from it to give total organic nitrogen, since in this way the amine-nitrogen (which may be high in an effluent from anaerobic processes) is included in the total nitrogen.

EXPERIMENTAL

Since the advent of more precise bacteriological methods, the nitrogen determinations in water analysis have lost their prestige. However, their offspring in sewage analysis still play a prominent part in treatment plant and stream pollution problems. The purpose of this paper is not to question the value of a nitrite or nitrate determination, but to inquire into the significance of the free and albuminoid ammonia and total organic nitrogen figures obtained in the routine analysis of domestic sewage.

The interpretation formerly placed upon these determinations in water analysis has been carried over into sewage practice. The bulk of the putrefactive material in sewage seems to be regarded as protein and protein derivatives. The free ammonia represents an end-product of bacterial decomposition; the albuminoid ammonia is attributed to peptones and amino acids; and the total organic nitrogen, as stated in Standard Methods (8) "comprises the nitrogen equivalent of nitrogenous compounds in various stages of hydrolysis, from complicated proteins to amino acids." Assuming the validity of this interpretation, the nitrogen would be expected to represent the concentration of putrefactive material or oxygen-requiring organic matter in the sewage. Our data for a purely domestic sewage, however, do not support these views.

The total nitrogen in the sewage can be almost entirely accounted

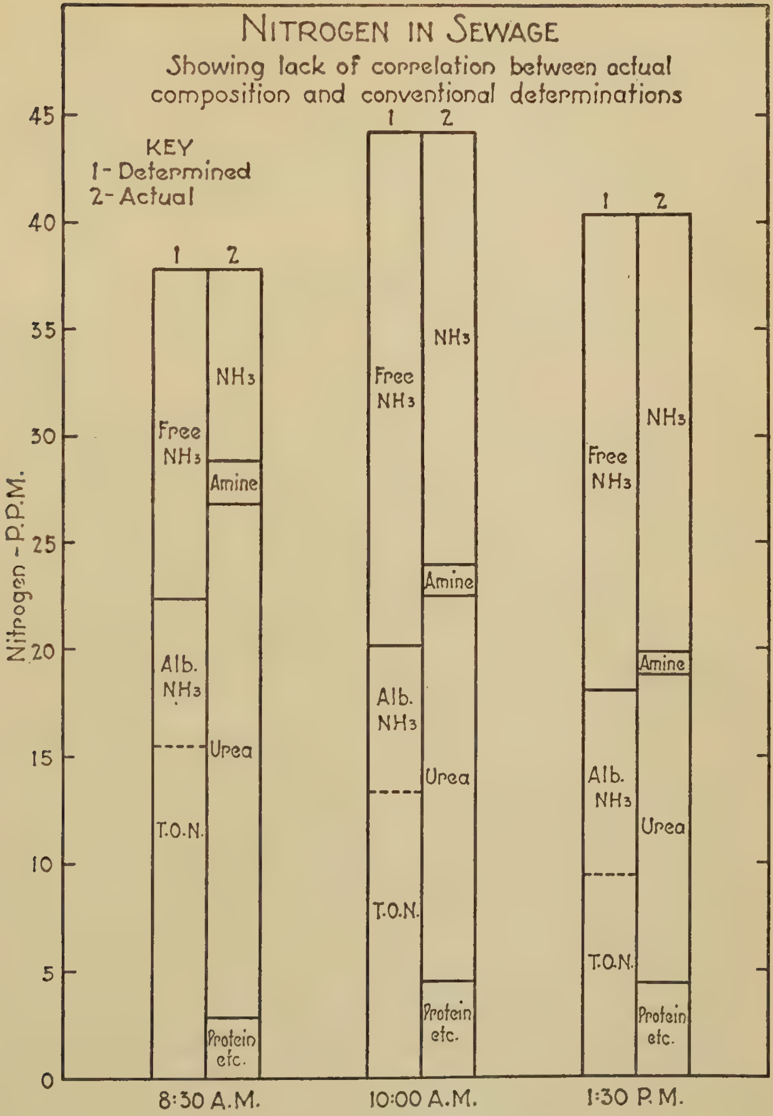

Fig. 1

for in the excreta of the population. A tabulation of the constituents of the excreta, as shown in the physiological chemistry texts (9, 10) reveals the following facts: over 90 per cent of the nitrogen is excreted as urea, and urea in being hydrolyzed by bacteria to ammonia and carbon dioxide has no oxygen demand. Only about 9 per cent of the excreted nitrogen is found in the feces, but associated with it is 97 per cent of the total oxidizable organic matter. In other words all but about 3 per cent of the oxygen demand of the excreta is associated with only a small variable fraction of the total nitrogen.

TABLE 1

*Excretion by normal adult per day**

	WEIGHT	CONTENT OF				OXYGEN REQUIRED TO PRODUCE CO_2 H_2O and NH_3
		Nitrogen	Carbon	Hydrogen	Oxygen	
	grams	*grams*	*grams*	*grams*	*grams*	*grams*
Urine (1500 cc.):						
Urea	35.0	16.35	7.00	2.33	9.33	0.00
Creatinine	1.0	0.37	0.42	0.07	0.14	0.85
Uric acid	0.75	0.25	0.27	0.02	0.21	0.21
Hippuric acid	0.70	0.05	0.45	0.04	0.19	1.13
Ammonia	0.65	0.53	0.00	0.12	0.00	0.00
Thiocyanates	0.15	0.02	0.02	0.00	0.00	0.05
Oxy-acids	0.06	0.00	0.04	0.00+	0.02	0.11
Oxalic, indican, etc.	Traces					
Mineral ash	30.0					
Totals	68.31	17.57	8.20	2.58	9.89	2.35
Feces (dry basis)	20.0	1.80	26.80	4.07	6.66	94.25
Totals		19.37	35.00	6.65	16.55	96.60

* Compiled from Hawk's Practical Physiological Chemistry and Mathew's Physiological Chemistry.

The oxygen demand for each component of the excreta has been obtained by calculating the weight of oxygen required to convert the component to ammonia, carbon dioxide and water after the method of Rideal (11). The oxygen required totals up to 97 grams per capita per day. The fact that this daily oxygen requirement compares favorably with statistical data obtained in stream pollution studies (12) is merely coincidence or balancing of errors, since our calculations disregard the oxygen demand of soap, paper, and similar material in the sewage.

Realizing then that urea is the main nitrogenous component discharged into the sewer and that it is slowly broken down by bacteria into ammonia, the nitrogen figures can be more adequately interpreted. The free ammonia represents urea already decomposed plus a litle chemically hydrolyzed during the distillation. Albuminoid ammonia represents further chemical hydrolysis of the urea; it is a notoriously indefinite determination and the explanation now becomes evident when the many factors, such as rate of distillation, concentration of alkali used, etc., which influence the slow hydrolysis are taken into account. The total organic nitrogen, of course, represents total nitrogen minus the free ammonia and includes most of the urea.

To verify this interpretation we have analyzed a number of domestic sewage samples both by the routine methods and by determining the separate nitrogenous components of the sample using the methods of the physiological chemist. The actual ammonia was aspirated into standard acid according to the Folin (13) procedure. The urea was then converted into ammonia (14) by adding the enzyme, urease, and the resulting ammonia similarly aspirated into standard acid. Total nitrogen was determined by the Kjeldahl method and the sum of the ammonia plus urea subtracted from it to give the protein fraction. Three such analyses are graphically represented in figure 1. In each case the constituents are reported in parts per million of nitrogen. The so-called free ammonia is seen to consist of actual ammonia together with a small amount of amine (which is unimportant in the present discussion) and part of the urea. The albuminoid ammonia results mainly from destruction of some urea by the boiling alkali, though a very small amount also arises from certain compounds grouped together as the protein fraction. This protein fraction, being as stated merely the difference between the total nitrogen and the sum of the components determined, includes not only the traces of other nitrogenous substances in the excreta, but also nitrogen containing material from the kitchen sink.

Although the purpose of this paper is not to discuss the nitrate determination, the predominance of urea introduces one error into the aluminium reduction method which deserves mention. As pointed out in Standard Methods, "during the long alkaline digestion some proteolysis may take place, giving high results." It is, however, not so much a proteolysis as a hydrolysis of urea especially during the distillation of the resultant ammonia. For example, our Imhoff tank effluent has consistently shown a nitrate content of 0.2 to 2.0 p.p.m. over a period of six months, while the colorimetric method has shown no nitrate. Accordingly whenever conditions pemit the colorimetric method would seem to be preferable to the reduction method.

To summarize, therefore, our analyses show, first that the main nitrogenous components of sewage are urea and ammonia; second, that these components bear no constant relation to the oxidizable organic matter; third that the albuminoid ammonia test, since it measures an indefinite portion of the urea, is worthless; and fourth the free ammonia also includes some of the urea and is erroneous if the distillation process is used. If it is considered desirable to continue the collection of nitrogen data in routine analysis, suitable methods could be chosen by Committee No. 1 for the accurate determination of the important nitrogenous constituents, and these methods adopted in place of the present indefinite ones.

One further point arising out of this discussion deserves mention; namely, the value of nitrogen determinations for detecting pollution in drinking water. We have collected a little data on this point, but not sufficient yet to make any final statement. Two cases naturally arise: if the water is polluted by sewage so recently that the urea has not been entirely hydrolyzed, the nitrogen determinations are subject to the errors discussed for sewage; however, the application to such waters of a method for the determination of urea alone, would give absolute evidence of sewage pollution, and it should not be very difficult to work out such a method.

On the other hand, if pollution were remote and all the urea had been broken down, the free ammonia should be less subject to error. But the albuminoid ammonia still seems to be of little importance. Our own tests have thus far confirmed some of the older literature (1, 2, 7) in showing that many organic substances slowly give up their ammonia when boiled with alkaline permanganate; and in this decomposition there is nothing to distinguish sewage material from decomposing plant remains. Similarly pollution of a water supply by an industrial waste containing proteins or peptones would not give any characteristic albuminoid ammonia result.

With the delicate analytical methods of the biochemist now at our disposal and the growing importance of river and lake pollution, there is an urgent need for the complete revision of our nitrogen determinations, with a view either to correcting their defects or abandoning them in favor of more significant determinations.

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(14) Hawk, P. B.: Ibid., p. 491–2.

SOCIETY AFFAIRS

FLORIDA SECTION

Waterworks operators, superintendents and engineers in the waterworks field met on November 18, 1926 in Tampa and organized the Florida Section of the American Waterworks Association. Over sixty men from all sections of Florida attended and took active part in the proceedings.

Papers were presented by Eugene Masters, president of the Florida League of Municipalities and city manager of St. Augustine; W. E. Darrow, consulting engineer of Winter Haven; Frank Schwabel, superintendent of the Clearwater waterworks. Mayor Wall welcomed the members of the association.

A paper submitted by Fred J. Stewart, city engineer of Hollywood, on the result of the hurricane to the waterworks men, brought forth much discussion as to the need for proper housing of waterworks records and the lack of knowledge of valve locations and other features of the distribution system.

A luncheon at the Katinka was followed by an inspection trip to the waterworks plant at Barritt Park. At the luncheon Commissioner Barritt spoke on the new Tampa waterworks. At the plant the party was shown all the details of operating procedure by C. C. Humphreys of the Waterworks Department. Comments on the neatness and general appearance of the plant could be heard on all sides. A short business session was held and the following officers were elected: Anson W. Squires, Tampa, Chairman; Eugene Masters, St. Augustine, Vice-Chairman; E. L. Filby, Jacksonville, Secretary-Treasurer.

Directors chosen were: C. C. Brown, Lakeland; A. P. Michaels, Orlando; W. A. Richards, Daytona Beach; F. W. Line, St. Petersburg; L. B. Duane, Sanford; F. J. Steward, Hollywood.

A constitution was adopted and it was decided to hold a spring and fall meeting with Hollywood as the next meeting place for the April meeting.

Those attending the meeting were invited by various manufacturers to a dinner at the Hillsborough Hotel. The Association adjourned after the evening entertainment. F. P. Larmon spoke on the new plant at Ft. Pierce during the dinner.

E. L. Filby,
Secretary.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Building a Valve for a Pressure of Three and a Third Tons. D. H. W. Felch. Chem. & Met. Eng., 33: 10, 596, October, 1926. Working pressure on pumps was increased from 1,500 pounds to 2,000 pounds. The valves as originally furnished were of the barrel type, high-tensile strength nickel alloy. The seats of one of the three pumps were of a good grade of cast gun bronze, of the second pump they were of the same nickel alloy as the valves, and of the third they were of hardened tool steel. After the pumps were put into service the nickel alloy and gun-bronze seats gradually pushed through the cylinder blocks. The hardened tool steel in the third pump remained in place, but the water being highly corrosive they pitted badly. Valves of a copper-aluminum-iron alloy and seats of copper-nickel-iron-chromium alloy were made. The valves showed slight pitting but the seats showed no erosion.—*John R. Baylis.*

Caustic Embrittlement of Steel. S. W. Parr and F. G. Straub. Chem. & Met. Eng., 33: 10, 604–7, 1926. The paper is a brief abstract of Bulletin 155 of the University of Ill. Embrittlement cracks follow grain boundaries. They do not follow the line of maximum stress, but start on the dry side of the plate. They run, in general, from one rivet hole to another, are irregular in direction, and never extend into the body of the plate beyond the lap of the seam. There is no elongation of the plate. The cracks always occur below the practical water level in seams under tension and at places where the high localized stresses occur. They occur in plates having perfect chemical composition and physical properties. There are certain areas, principally in the Middle and South West United States where embrittlement is more evident than in others. Cases that can be traced to water treatment are comparatively few. The type of boiler seems to be without effect as far as tendency towards embrittlement is concerned. The importance of the sulfate-carbonate ratio in preventing embrittlement has been studied in the Univ. of Ill. power plant over a period of 10 years. The sulfate-carbonate ratio of the feed water is maintained at two by neutralizing about 70 per cent of the sodium carbonate alkalinity with sulfuric acid. After 10 years of operation on this treatment the drums were found to be in perfect condition.—*John R. Baylis.*

Boiler Corrosion and Possible Combative Measures. W. M. Barr and R. W. Savidge. Chem. & Met. Eng., 33: 10, 607–8, October, 1926. The highpriced alloys do not appear to be an economical substitute for steel. After scale accumulates the water is kept from contact with the steel and the high temperature on the firebox side soon overheats the metal where the scale is thickest. Burning of the metal makes it more easily attacked by the corrosive elements of the water. When the scale cracks off water comes in contact with the burned metal and ideal conditions are set for electrolytic action. Dissolved oxygen, when introduced into the boiler with the feed water, is one of the principal causes of corrosion. A great improvement has been effected by passing the water through an open feed water heater in which the temperature was held above 200°F. The principal benefit of water treatment is the removal of incrusting matter. High concentrations of sodium salts appear to accelerate corrosion and in practice it is desirable to operate locomotive boilers on concentrations below 3500 to 4000 parts per million. Further reduction of concentration is not economical on account of fuel loss. Present practice in treating feed water is to remove the incrusting solids and carry a slight excess of caustic soda on account of its inhibitive effect on corrosion. Too great an excess of caustic soda or sodium carbonate may cause foaming.—*John R. Baylis.*

Comparative Degree of Thyroid Enlargement Among School Children in Two Sections of Louisiana. L. C. Scott. Quarterly Bulletin, Louisiana State Board of Health, **17**: 2, 72, June, 1926. A thyroid survey, conducted among the school children of four parishes in Louisiana, indicates iodin deficiency. This is greater in the river parishes of St. James and St. Charles, where rain water is used for drinking, than in the forest parishes of St. Tammany and Washington, where the water supply comes from deep wells.—*G. C. Houser.*

Troubles. E. L. Filby. Health Notes, Florida State Board of Health, **18**: 8, 112, August, 1926. A district engineer of Florida State Board of Health accidentally discovers and eliminates cross-connection between mains of a privately owned and operated water company and those of a municipally owned high-pressure fire protection system, using grossly polluted lake water. Connection had been made inside a power plant, without knowledge of water company or of city.—*G. C. Houser.*

Typhoid Epidemics in Two Pennsylvania Towns. Listening Post, Penn. Dept. of Health, **4**: 38, 21 and 23, May and June, 1926. Water-borne typhoid epidemics recently occurred in New Milford and Glenshaw. New Milford, with a population of 600, had 74 cases and 4 deaths. Glenshaw had 15 cases of typhoid at one time, all children with a single exception. Here the source of infection proved to be a school well.—*G. C. Houser.*

Court Sustains Order re Water Supply Pollution. Connecticut Health Bulletin, **40**: 5, 127, May, 1926. Inspection of the Winsted public water supply having disclosed a serious case of pollution, State Department of Health granted a hearing on December 21, 1925, to property owner concerned. In spite of the fact that his property drained into brook tributary to Winsted reservoir, it was found that in 1925 a barnyard had been located very close to the brook. An order for the removal of the barnyard, issued by the department, was sustained by the court on March 30, 1926.—*G. C. Houser.*

Appraisal of Health Service for the Year 1925 in Fifteen Illinois Cities. Ill. Dept. of Pub. Health, Ill. Health News, **12:** 5 and 6, May–June, 1926. Water supply is one item dealt with in survey of public health services provided by 15 cities with populations ranging from 30,000 to 100,000. In all except two of these public water supply meets governmental standard. In Joliet, where the storage basins are subject to pollution, supply has been given provisional certification only. In Moline, the water supply does not fully meet requirements as to safety, owing to deficiency in construction and size of purification plants.—*G. C. Houser.*

Value of Automatic Sprinkler Systems. L. S. Jones. Virginia Municipal Review, **3:** 10, 392, October, 1926. Gives many arguments for installation of automatic sprinkler systems for fire prevention in Richmond, Va. Examples given of saving effected in cost of insuance after installation of sprinklers. Depending upon whether temperature in a plant may, or may not, go below freezing point, the dry pipe, or the wet pipe system should be used.—*G. C. Houser.*

Outbreaks of Typhoid Fever in New Jersey. Public Health News, New Jersey Dept. of Health, **11:** 11, 256, October, 1926. Forty-four outbreaks of typhoid were investigated during 1925 by the Bureau of Local Health Administration. The largest outbreak included cases in 15 municipalities in Bergen, Hudson, and Passaic counties. The source of infection was found to be a spring at Hook Mountain bathing beach, near Nyack, N. Y.—*G. C. Houser.*

Floods Create Health Problem. C. D. Gross. Illinois Health News, **12:** 10, 345, October, 1926. Slowly rising streams seldom cause deaths by drowning but neglect of sanitation during and following high water may cause epidemics of disease, such as typhoid fever. During flood stages, drinking water should be secured only from wells known to be safe. Water from wells near flood water should be boiled before use for drinking. After the flood passes, dug wells must be sterilized with chloride of lime and thoroughly cleaned out.—*G. C. Houser.*

Survey of Lake Resorts. Public Health News, New Jersey Dept. of Health, **11:** 11, 260, October, 1926. A survey of lake resorts shows great need for better supervision over the sanitation of the large number of summer resorts in New Jersey. At one lake the shallow wells which supply drinking water were menaced by nearby privies and cesspools. At another resort the cesspools receiving sewage from two hotels were found to be overflowing directly into the lake which at times is used as water supply for the Borough of Branchville. Theoretically, work of supervision should be performed by local health officials.—*G. C. Houser.*

Suburban Sanitary Engineering. H. B. Costill. Public Health News, New Jersey Dept. of Health, **11:** 10, 216, September, 1926. Water supplies of bay shore and ocean front communities are usually obtained from driven wells. These waters usually are high in carbon dioxide and iron, making the water offensive to the user. Problem arises whether Dept. of Health shall consider the iron and CO_2 contents of a water supply as influencing "the purity of the supply of potable water" furnished by a water plant.—*G. C. Houser.*

Arctic and Hudson Bay Drainage (and Mississippi Drainage in Canada) in Alberta, Saskatchewan, Manitoba and Western Ontario. Water Resources Paper, 44: 1925, Dominion Water Power Branch, Dept. of Interior, Ottawa. Hydrometric investigations during climatic year ending September 30, 1923.—*M. H. McCrady.*

Atlantic Drainage (south of St. Lawrence River) New Brunswick, Nova Scotia, Prince Edward Island. Water resources Paper, 45: 1925, Dominion Water Power, and Reclamation Service, Dept. of Interior, Ottawa. Hydrometric operations for the two year period ending September 30, 1924.—*M. H. McCrady.*

Arctic and Hudson Bay Drainage (and Mississippi Drainage in Canada) in Alberta, Saskatchewan, Manitoba and Western Ontario. Water Resources Paper, 46: 1926, Dominion Water Power and Reclamation Service, Dept. of Interior, Ottawa. Hydrometric investigations during climatic year ending September 30, 1924.—*M. H. McCrady.*

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St. Lawrence and Southern Hudson Bay Drainage, Ontario. Water Resources Paper, 49: 1926, Dominion Water Power and Reclamation Service, Dept. of Interior, Ottawa. Hydrometric investigations for climatic years 1923–24 and 1924–25.—*M. H. McCrady.*

Annual Report, 1924–25, Dominion Water Power and Reclamation Service. Dept. of Interior, Ottawa, Canada. Present turbine installation to date, 3,569,275 HP, represents only 8½ per cent of total available.—*M. H. McCrady.*

Influence of Metallic Elements on the Corrosion of Iron and Steel. YUHATIRÔ UTIDA and MAKOTA SAITÔ. Sci. Repts. Tokohu Imp. Univ., 14: 3, 295–312, 1925. (In English.) From Chem. Abst., 20: 573, February 20, 1926. Effect of nickel, chromium, silicon, copper, manganese and tungsten on corrosion of iron and steel was studied. Samples were prepared by casting pure iron alloyed with above metals, and castings were cut into rods 4 to 5 cm. long and 5 mm. in diameter. Clean, polished rods were immersed for 24 hours at room temperature in beakers containing 10 per cent nitric, hydrochloric or sulphuric acid and loss in weight recorded. Oxidation at high temperatures was measured by placing specimens for 1 hour in electric furnace at 1100° and recording increase in weight. Iron containing 14 per cent chromium is not attacked by nitric acid, but is easily corroded by hydrochloric acid of same concentration. Increasing amounts of nickel, silicon and tungsten decrease corroding action of acids and oxidation in air at 1100°. Addition of manganese always increases corrosion. Copper increases attack by nitric acid, while hydrochloric and sulphuric acids affect copper alloys little or not at all. While iron containing chromium is easily corroded by hydrochloric acid and iron containing nickel very little, combined effect of both produces alloys highly resistant to hydrochloric and sulphuric acids. For steels the best results in hydrochloric acid were obtained when carbon content varied between 0.1 and 0.7 per cent, and in sulphuric acid when 0.3 per cent carbon was present. Mixed acids corrode alloys to greater extent than pure acids. Alloy containing 0.4 per cent carbon, 20 per cent chromium and 8 per cent nickel, resembling Krupp's rustless steel V_2A, has best corrosion-resisting properties, both in pure and mixed acids.—*R. E. Thompson.*

The Use of Lime for Treating Public Water Supplies to Prevent Corrosion and "Red Water." J. R. BAYLIS. Rock Products, 28: 18, 59–60, 1925. From Chem. Abst., 20: 637, February 20, 1926.—*R. E. Thompson.*

A Sensitive Biological Indicator for the Chemical Condition of Inland Water. AUGUST THIENEMANN. Naturwissenschaften, 13: 868–9, 1925. From Chem. Abst., 20: 637, February 20, 1926. It has been observed that the very common water flea, *Gammarus pulex*, only lives in those waters that have relatively high oxygen content, combined with rapid oxygen replenishment. It is sensitive to all inorganic pollution and to decaying organic matter. Even more sensitive test objects for quality of water are the epizoic protozoa, *Spirochona gemmipara* and *Dendrocometes paradoxus*, occurring on the "Kiemenblättchen" of Gammarus. They are relatively resistant to temperature changes but do not appear when appreciable sodium chloride, acids, or ogranic pollution is present, even when the flea itself is unharmed.—*R. E. Thompson.*

Difficulties Encountered in Purifying Small Quantities of Boiler Feed Water. G. PARIS. Chimie et industrie, Special No. 143, September, 1925. From Chem. Abst., 20: 637, February 20, 1926. Lime-soda process can hardly give good results with flow of less than 5 tons an hour. Processes using addition of dissolved reagent can give good results with flows down to 600 liters an hour. Zeolite processes give good results with flows of less than 500 liters per hour.—*R. E. Thompson.*

Modern British Practice in Water Softening. IV. Lime Cream and Soda Ash Plants (Kennicott, Lassen-Hjort, Paterson and Porter). D. BROWNLIE. Ind. Chemist, 1: 495–500, 1925; cf. C. A. 19: 3553. From Chem. Abst. 20: 637, February 20, 1926.—*R. E. Thompson.*

Lime Treatment of Water for the Manufacture of Raw Water Ice. A. S. BEHRMAN. Rock Products, 28: 18, 57–8, 1925. From Chem. Abst., 20: 637, February 20, 1926.—*R. E. Thompson.*

Sodium Silicate as a Corrosion Preventive. R. P. RUSSELL. Proc. Am. Assoc. Textile Chem. Colorists, 1926, 47–51; Am. Dyestuff Rept., **16**: 61–5. From Chem. Abst., **20**: 896, March 20, 1926.—*R. E. Thompson.*

Results of Tests with Alcement Lafarge. A. F. R. LUND. Teknisk Ukeblad, **72**: 324–7, 335–40, 350–2, 1925. From Chem. Abst., **20**: 651, February 20, 1926. Alcement, manufactured by Sté. Ame. des Chaux & Ciments de Lafarge et du Teil, France, was compared with normal portland cement. Setting properties were normal and soundness was satisfactory. Hardening was extremely rapid, and major portion of ultimate strength was reached in 24 hours. After 28 days, tensile strengths of the two sand mortars were nearly alike, with only 10 per cent difference in favor of alcement, but crushing strength of latter was nearly twice that of portland cement mortar. In concrete the superiority of alcement as regards crushing strength was still greater. Humic acids in the sand have only a small influence upon quality of this mortar. It was very resistant to fire and water, and was slightly more resistant to wear. Large test specimens of concrete, plain and reinforced, proved great and general superiority of alcement.—*R. E. Thompson.*

Operation of Swimming Pools. W. WEICHARDT and O. ULSAMER. Gesundh. Ing., **48**: 283–5, 1925. From Chem. Abst., **20**: 638, February 20, 1926. Purification of pool water with chlorine and by filtration is practiced in Germany. Excess of chlorine at all times, and a bacterial count resembling that of drinking water, recommended. Results given for pool at Nürnburg.—*R. E. Thompson.*

Lime in the Treatment of Dye and Textile Wastes. F. D. SNELL. Rock Products, **28**: No. 18, 61–2, 1925. From Chem. Abst., **20**: 668, February 20, 1926. Description of acid neutralization and coagulation of dye wastes by iron or aluminum sulfate and lime. High calcium lime is preferable to magnesian lime.—*R. E. Thompson.*

The Radioactivity of the Mineral Waters of Hammam Meskoutine, Algeria. I. POUGET and D. CHOUCHAK. Compt. rend., **181**: 921–3, 1925; cf. C. A., **19**: 3214. From Chem. Abst., **20**: 702, March 10, 1926. Radioactivity of several springs in district varies from zero to 13.7 millimicrocuries per liter.—*R. E. Thompson.*

Modern Developments in Steels Resistant to Corrosion. W. H. HATFIELD. Engineering, **120**: 657–60, 1925. From Chem. Abst., **20**: 731, March 10, 1926. Theories of corrosion are briefly described. Modern conception is that nature of first thin oxide film determines subsequent chemical action. Corrosion tests are always disturbed by accelerating or retarding factors, such as contact of specimen with solid body, improper aëration, or change of composition of medium. Data are given on results of tests of alloys and corrosion-resisting steels.—*R. E. Thompson.*

The Economy in the Electric Arc Welding of Ingot Iron. KARL MELLER. Siemens-Z., **5**: 457–64, 1925. From Chem. Abst., **20**: 734, March 10, 1926.

Recent increasing application of electric arc for welding ingot iron is due to better economy in the working method. Welding is at present only undertaken with metal electrodes, directly molten into the seams. Data given in regard to technology and efficiency. Electric arc welding of an oil tank showed an actual saving of 50.6 per cent over autogenous welding.—*R. E. Thompson.*

The Radioactivity of the Water of the Thermal Spring at Chaudfontaine, Belgium. Eug. Prost. Rev. universelle mines; 8: (7) 21–8, 1925. From Chem. Abst., 20: 789, March 10, 1926. Results of recent analysis given. Experiments revealed presence of radium emanation, content being of order of 2–3 millimicrocuries per liter. The water freed of this emanation by boiling showed slight activity after several days, though it was not proved whether this was due to residual emanation or to presence of radium in water.—*R. E. Thompson.*

Chemical Supervision of Plants for Softening of Boiler Water. A. Splittgerber. Z. Nahr. Genussm. 50: 142–77, 1925. From Chem. Abst., 20: 790, March 10, 1926. Review, with excellent bibliography, of soda, lime-soda, and permutite processes, including discussion of methods of determination and allowable limits of various impurities.—*R. E. Thompson.*

The Problem of Sewage Disposal in the Ems and Ruhr Territory. Jan Smit. Chem. Weekblad, 22: 537–41, 1925. From Chem. Abst., 20: 790, March 10, 1926. Problem is particularly difficult because of dense population and network of coal mines. Phenols and chlorophenols from gas, coke, and other industries threaten the fisheries, not so much by direct toxic effect as by impairing taste of the fish. They are removed from sewage water by biological oxidation on porous surfaces and aëration according to Fowler and Bach, or extracted with benzene from the gas water.—*R. E. Thompson.*

Separation of Small Quantities of Calcium from Large Quantities of Magnesium in Water. H. Noll. Chem.-Ztg., 49: 1071–2, 1925. From Chem. Abst., 20: 790, March 10, 1926. Some 65 careful experiments showed that the oxalate method, which has recently been criticized, is indeed satisfactory, provided separation is effected in 200 cc. of water when not over 125 mgm. of MgO is present.—*R. E. Thompson.*

Treating Alumino-Silicate Minerals for Water-Softening. Herman Reinbold. U. S. 1,570,006, January 19, 1926. From Chem. Abst., 20: 790, March 10, 1926. Minerals of the bentonite variety are ground, sized, calcined, treated with a solution of aluminum compound such as aluminum sulfate, sodium hydroxide, and sodium chloride, and dried.—*R. E. Thompson.*

Apparatus for Deaërating Boiler Feed-Water, etc. Griscom-Russell Co., Brit. 234, 448, May 24, 1924. From Chem. Abst., 20: 791, March 10, 1926. A portion of the incoming liquid is distributed in the apparatus in form of curtain of falling drops through which the evolved gases and vapor pass to condense latter.—*R. E. Thompson.*

The Science of Ground Water Supplies. G. Thiem. Z. Ver. Gas-u. Wasserfach, 65: 166–9, 1925. From Chem. Abst., 20: 956, March 20, 1926. Most German cities use ground water as civic supplies.—*R. E. Thompson.*

Ammoniacal Liquor and Noxious Effluents from Distillation Plants. J. W. Young. Annual Report of Alkali, etc., Works Inspector. Gas World, **82**: 647–50, 1925. From Chem. Abst., **20**: 813, March 10, 1926. Liquors from vertical report systems are highly charged with higher tar acids, color-producing substances, etc. Liquors from horizontal retort plants are relatively free from such substances. Phenol is considered the most obnoxious constituent. Its removal is effected by scrubbers in which flue gases are injected into the base, the injector working at steam pressure of 70 pounds. Liquor enters at 91° and leaves at 95°. Phenol volatilization efficiency of 94 per cent and reduction in oxygen absorption value of 34 per cent is claimed.—*R. E. Thompson.*

Potentiometer for Routine Determinations. C. W. G. Hetterschij. Chem. Weekblad, **23**: 3–4, 1926. From Chem. Abst., **20**: 845, March 20, 1926. Apparatus described has advantage of cheapness, simplicity, direct pH reading, and sturdiness. Measuring range is pH 3.5 to 8.5. Rheostat and resistance unit for rough and fine regulation are arranged on both sides of circular constant resistance unit, subdivided into equal manganin coils with 100 dials. Thus the pH difference between 2 dials is 0.05. Accuracy can be further increased by taking average of 2 galvanometer readings.—*R. E. Thompson.*

A Hydrogen Electrode for Flowing Liquids. A. H. W. Aten and P. J. H. van Ginneken. Rec. trav. chim., **44**: 1012–38, 1925. (In English.) From Chem. Abst., **20**: 847, March 20, 1926. A H-electrode developed by authors (Tijdschr. Alg. tech. Ver. Beetwortelsuikerfabr. en. Raff. 5: 89, 1924–5) is described and illustrated, and its application outlined.—*R. E. Thompson.*

The Value of the Lehmann Microelectrode. G. E. Vladimiro and M. J. Galivialo. Biochem. Z., **160**: 101–4, 1925; cf. C. A. **18**: 2. From Chem. Abst., **20**: 847, March 20, 1926. Good results were obtained in determination of pH in carbon dioxide-free solutions. When carbon dioxide was present, the method compared favorably in exactness and speed with other methods.—*R. E. Thompson.*

The Metallurgical Aspects of Modern Boiler Practice. L. P. Sidney. Chem. Age (London), **14**: 2–3, 1926. From Chem. Abst., **20**: 893, March 20, 1926. Growing necessity of fuel economy is causing changes in boiler pressures and temperatures and, therefore, in boiler construction. Consensus of opinion is that strength of boiler plate can be satisfactorily increased by use of steel of high quality containing certain amounts (as yet undetermined) of nickel and chromium.—*R. E. Thompson.*

The Nature of the Protective Film of Iron. T. Fujihara. Trans. Am. Electrochem. Soc., **49**: 1926 (preprint); cf. C. A. **18**: 1970, 2677. From Chem.

Abst., 20: 895, March 20, 1926. When a drop of distilled water is placed on polished surface an uncorroded rim appears at edge of drop. Author found that liquid on this uncorroded portion was alkaline in reaction due to presence of soluble ferrous hydroxide. Presence of carbon dioxide destroys this protective film by neutralizing the alkalinity, permitting corrosion to continue.—*R. E. Thompson.*

The Rustproofing of Materials. M. E. McDonnell. Mech. Eng., **47**: 875–80, 1925. From Chem. Abst., **20**: 895, March 20, 1926. Tests by Pennsylvania Railroad showed steels which contained 0.25 per cent copper to be twice as resistant in atmosphere as non-copper-bearing steel. Paint on steel coaches is based on in steam sheds at 120° and lasts 3 years compared with 1.5 years for air-dried finishes.—*R. E. Thompson.*

Coating Sheet Iron with Lead. Apparatebau, **37**: 327–8, 1925. From Chem. Abst., **20**: 896, March 20, 1926. Pickel in sulfuric acid bath, wash free from acid, immerse in antimony chloride solution until surface turns deep black, wash, treat with zinc chloride, dip in molten lead and cool in oil. Coating becomes so firmly attached that bending and hammering will not detach it. Cf. C. A. **16**: 1068, 2104, 3627; **18**: 524, 2679.—*R. E. Thompson.*

ABSTRACTS, SUB-COMMITTEE NO. 9

Joint Research Committee on Boiler Feedwater Studies

Composition of Water and Injurious Constituents it Contains. (Composition des eaux naturelles et éléments nuisibles qu'elles peuvent contenir). J. Guth. Assns. Françaises de Propriétaires d Appareils à Vapeur, Bul. No. **25**: July, 1926, pp. 161–180, 3 figs. Discusses chemical constituents of water and importance of accurate analysis; gases, minerals and organic compounds; water hardness, temporary and permanent; typical feedwater analysis.

Recorder for Dissolved Oxygen in Feed Water. Engineering, 122: 3174, Nov. 12, 1926, p. 610, 2 figs. Instrument, known as Cambridge dissolved-oxygen recorder, gives continuous record of quantity of oxygen present in feed water on chart calibrated in cubic centimeters per liter so that defects on feed system which might otherwise remain unnoticed for long periods, may be instantly detected and remedied.

The Preservation of Boilers and Condensers from Incrustation and Corrosion by Means of Electric Current. J. Frankfurt. Electritchestvo, 7, July 1926, pp. 315–318, 5 figs. Review of methods of water purification used in boiler feeding and employed in Russia and other countries. (In Russian.)

Treatment of Feed Water. Natl. Elec. Light Assn. Report, no. 256–71, July, 1926, 30 pp., 21 figs. Results in several plants with use of sodium aluminate as accelerator in outside treating systems, and experience with acid-treating apparatus used in connection with zeolite system; scale troubles in interdeck and radiant-heat-type superheaters; boiler-scale troubles in high-pressure plant, which has been endeavoring to maintain suggested sulphate-carbonate ratio; caustic-embrittlement troubles with boilers at Long Beach steam plant of Southern California Edison Company; acid treatment of boiler water as developed by Dallas Power and Light Co.

Measuring Boiler Load Without Flow Meters. J. D. Jenkins. Power, **64:** 18, Nov. 2, 1926, p. 658. Author makes use of principle that what comes in minus what goes out must equal what stays; this principle is applied to dissolved solids in water entering boiler; from analysis of feed and boiler waters and knowledge of time, boiler has been on and quantity of blowdown, evaporation can be calculated.

Overcoming Scale in Boilers. D. Cochrane. Power House, **20:** 20, October 20, 1926, pp. 15–16. Author shows some causes of scale formation and outlines various methods to overcome its effects, dealing particularly with troubles caused when oil and scale combine in boiler.

The Prevention of the Formation of Boiler Scale. Engineering, **122:** 3168, October 1, 1926, pp. 415–416, 5 figs. Water-cooled type of apparatus known as filtrator, which is now being used to prevent formation of boiler scale and for removal of old deposits; process consists in introducing water-soluble constituent of linseed into water which is fed into boiler, in such a way that no oil enters with it; with new modification, old trouble has been entirely eliminated; details of other modifications.

Condenser Tube Scaling Tools. Engineering, **122:** 3174, November 12, 1926, p. 611, 2 figs. Describes tool for removal of condenser scale which has proved particularly useful in power station work, where matter of some 8000 tubes perhaps 17 feet long, may have to be dealt with.

Means of Preventing Boiler Pitting. C. H. Koyl. Ry. & Locomotive Eng., **39:** 10, October, 1926, pp. 278–279. Author shows that it is easier to exclude oxygen from locomotive boiler than from stationary boiler or any closed water system; on districts with treated or naturally soft water there is no difficulty in preventing pitting with present open heater nor in materially reducing it by closed heater or even with closed-overflow injection properly chosen and properly operated.

Investigation of Strongly Corroded Brass Condenser Tubes (Untersuchungen von Messingkondensatorrohren mit starker Korrosion). M. Schwarz. Korrosion u. Metallschutz, **2:** 1, January, 1926, pp. 8–17 17 figs. Examination of tubes from two power plants showed basic zinc carbonate in corroded spots and experiments showed that cooling water attacked beta mixed crystals of brass.

NEW BOOKS

Der Beton. Richard Grün. Berlin: Julius Springer. Paper; 186 pp. Reviewed in Eng. News-Rec., **96**: 823, May 20, 1926.—*R. E. Thompson.*

Einflüsse auf Beton. F. Hundeshagen, Otto Graf and A. Kleinlogel. Berlin: Wilhelm Ernst & Sohn. Paper; 448 pp.; 19.5 M. Cloth, 21.6 M. Reviewed in Eng. News-Rec., **96**: 995, June 17, 1926.—*R. E. Thompson.*

Lead Poisoning. Joseph C. Aub, A. S. Minot, Lawrence T. Fairhall, and Paul Reznikoff. Baltimore: The Williams & Wilkins Co. $4. From Chem. Abst., **20**: 636, February 20, 1926.—*R. E. Thompson.*

Neuere Volksbäder. P. Böttger. Berlin: Deutschen Gesellschaft für Volsbäder. 56 pp. Reviewed in Gesundh. Ing., **48**: 541, 1925. From Chem. Abst., **20**: 638, February 20, 1926.—*R. E. Thompson.*

Wasserversorgung und Brunnenbau. Groh. Berlin: Laubsch and Everth. 173 pp. M. 5.50 Reviewed in Gesundh. Ind., **48**: 270, 1925. From Chem. Abst., **20**: 638, February 20, 1926.—*R. E. Thompson.*

The Chemistry of Power Plant. W. M. Miles. London: E. Benn, Ltd. 144 pp. 6s. Reviewed in Ind. Chemist, **1**: 502, 1925. From Chem. Abst., **20**: 658, February 20, 1926.—*R. E. Thompson.*

Korrosion and Rostschutz. Emil Maass. Berlin, S. W. 19: Beuth Verlag. 35 pp. R.M. 1. From Chem. Abst., **20**: 734, February 20, 1926.—*R. E. Thompson.*

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THE PROPOSED AQUEDUCT FROM THE COLORADO RIVER[1]

BY WILLIAM MULHOLLAND[2]

Preparatory to the introduction of the subject assigned to me, that is, the proposed aqueduct from the Colorado River, I will have to precede whatever remarks I have to make on that topic by first pointing out the necessity of such a project. It is all very well to say, "We will bring water from the Ganges or the Brahma putra," but first we must show the need of it to our patrons, the public. Before going on to that point, I want to say something about the impressions I received and about the various meetings of this organization today. I have always held very strongly for Christian principles (I am not going to preach a sermon, however); always having held that the amenities of civilization require that people meet in close association. I met possibly one hundred people of this group today; they are commonly, when I meet them, in the attitude of rivals and in a hostile attitude to each other when they meet in my office; they are rival bidders upon machinery and water works appliances; they always come in with a scowl when they meet the other fellow there and although always refraining from anything discourteous, just the same there is always that spirit of hostility.

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[1] Presented before the California Section meeting, October 28, 1926.

[2] Chief Engineer and General Manager, Bureau of Water Works and Supply, Los Angeles, California.

I have often wondered whether it could be eliminated and I found today that it could be by the appliance of Christian principles. I saw more Christian principles today than I ever saw exercised in my whole experience. I once knew a man who followed those Christian principles; he believed in the rules of propinquity and the fact that a close association and intimate knowledge of the character of those with whom he came in contact always brought about a better understanding; that man was unfortunate enough to lose his wife in early years—a great misfortune to him, but he turned around and married his mother-in-law. Now, all of these men today, I notice, were in a mood, should they be bereaved in this way, to really turn around and marry their mothers-in-law.

Before proceeding with the subject of the Colorado River, it is proper that we should show some reason for the venture. For that reason I wish to advert a little to the present condition of the city of Los Angeles and to the motive that impels her to look so far distant so soon after the great adventure of some twenty years ago, to-wit: the building of the Los Angeles Aqueduct. I was the sponsor of that project as I am of this one. Being responsible for this project and considering the necessity of the occasion as at the end of the drouth following the years 1902–3, we were at our wits end for a water supply in the city of Los Angeles and there was an impending shortage. If the drouth had lasted another year or two that would have ended the city of Los Angeles. We were afraid of that, but a normal rainfall came and we got along for another ten years or so by reason of the fact that there was a restoration of the normal precipitation. We are now, I hope, near the end of another, a very disastrous and long continued period of drouth. We all know,—all of you who study the water supply of this district, that we are on tenterhooks as to where the next year's supply is coming from, or the year after that, and you all know that we have had a drouth of very drastic and fierce persistence up and down this State. The ground waters have receded; the streams have dried up; the lakes have dried up and all of the rest of the things have happened until the water situation leaves us on the verge, not of total destruction, but of great distress. If we do not get a rainfall within a year or two this city will suffer a knockout blow for many years that will suppress and check many useful projects for the public weal in this State.

This matter was presented to the city of Los Angeles as it was to the city of San Diego and every other city up and down the coast from

San Francisco,—even from the Siskiyou clear to San Diego and even further north.

To my great surprise the cities of Portland and Seattle are also complaining, not on account of any insufficiency of the water supply which is within striking distance of those cities, but the storage facilities for their respective water supplies were not adequate to meet the conditions of drouth that have presented themselves within the last few years. We have to be forehanded. Of all other professions in the world, the man with the responsibility of supplying a city with water has to be forehanded. He must look ahead and look a long way ahead, discounting every possible sort of condition that may arise. You cannot get up in my position—and many of you know the position I am in here—you cannot get up and make excuses to your employer, your public. You must guess your crowd, plunge, go ahead and for their welfare provide an adequate water supply. It is allright if they reject your proposals. You are excused. But if you do not present the matter in a positive way to the people and some disaster occurs, you are at fault and you cannot evade the responsibility.

The people of the city of Los Angeles are not acquainted with the disaster that impends by reason of her prosperity. Prosperity is not always good, it gets people off the alert and they disregard a proper sense of security.

The major part of the city of Los Angeles is located south of the Santa Monica Mountains. There are frequent checks made from time to time to determine the tendency of the city's expansion. The people in the city of Los Angeles have not induced that tendency. It is the people lying outside of the city of Los Angeles that want to pull the blanket over their feet to obtain a share of the water supply. There is scarcely a month passes that we are not appealed to by people around the rim, much to our resistance,—for what?—to get a share of the city's water supply. Now we have had to extend and extend until at the present time the area of the city of Los Angeles is 430 square miles. That is the size of the city we have to supply and you will all appreciate the fact that it does not make for a cheap water supply or water works.

The population, as determined by many observations, at the present time is more than 1,200,000. The population of the city per square mile is 2700. Imagine a diffused population like that spread over such an area. To provide a city of that size with water requires 2800 miles of main pipes; more than one-tenth of the distance around the world. The mileage of main pipes in the city has been doubled within the last five years. The number of services is 240,000. The domestic water consumption of the city in summer is 152,000,000 gallons; in winter 123,000,000 and a mean of 138,000,000 gallons per day.

I recall when I first did some work for the northern cities, the consumption of water in the city of Oakland was about 16,000,000 or 17,000,000 gallons per day, the consumption in San Francisco was close to 40,000,000 gallons per day. I do not know, however, what the consumption of those cities is today, but possibly double what it was at that time. Compare that with the city of Los Angeles, with 138,000,000 gallons per day.

The city of Los Angeles is virtually on the edge of a desert. You may go in any direction from the city, north, south, east or west and you will find the desert before you go very far;—the arid, grinning desert.

The city of Los Angeles had to go 250 miles to the north, over three mountain ranges, and across deserts and waste plains to the Owens River to get her last water supply. Why has she outgrown this supply so rapidly? The very fact itself that she got it, attracted the people to our city. It added tremendous prosperity and attractiveness and brought people here.

I recollect when I was campaigning for the bonds for that water supply, people would ask, "How long will that last you?" I believed fully in the growth of the city, but never felt it would reach its present proportions in such a short span of years. I am, and always was, the greatest pessimist on the question of the growth of the city of Los Angeles and I hope she stops tomorrow. But she grows in spite of me. Yet people would ask me, "How long would that last?," and I would say, "It will last until she grows—until we have a population of one million people; as soon as we get a million people we will have to seek another water supply."

We now have a million and one-quarter population and we are still living on the old water supply with the population still increasing as rapidly as ever and very naturally I am still in the same nightmarish state of mind as I was thirty years ago.

We pump water in the city of Los Angeles. The criticism offered to the proposed aqueduct from the Colorado River to Los Angeles, is that we will not be able to pay the cost of pumping this water by the time we get it to Los Angeles. We know what it costs to pump water. Our pumped water at the present time is 80,000,000 gallons per day. That is more than San Francisco and Oakland use, yet we pump that quantity. You cannot scare us with pumping water, if we can get water with no very great taxation but that of pumping.

In addition to that, the Colorado River carries with it the proposition of power development. There is tremendous power to be developed and I will say that we propose to develop it. A quantity of 1500 second feet of water will require just about one-third of the power that can be developed at the Boulder Canyon Dam. You cannot put power to better use insofar as Los Angeles is concerned, or insofar as California anywhere is concerned, than to pumping water for profitable use.

We can pump the water there if we get the power at cost plus cost of operation, say for 5 cents per 100 cubic feet, as we are selling water today in Los Angeles for 13 cents per 100 cubic feet. So it will be seen that there is a good margin before we reach the limit of 20 cents per 100 cubic feet. The cities of Oakland and San Francisco charge 25 or 28 cents per 100 cubic feet and I claim right now that that is cheap water. Why should a man get water, the essential element of life, more cheaply than the cost to him of polishing his shoes or paying for his telephone? The telephone rates in Los Angeles are far in excess of the rates for water. They should not be. We can stand to pay far more than we do at the present time for water. I am not protesting against the existing rates for water in the city of San Francisco or Oakland as I have always found that the rates are perfectly justified. The people who brought the water there and entered the field of supplying those two great cities with it were justified in making the rates which they did. The rates which they made were approved by the State Railroad Commission.

If we can get water into the city of Los Angeles, through an aqueduct, from the Colorado River, for 20 cents per 100 cubic feet, and I am certain that we can, we shall still have a cheaper water than the average large city in the United States. Remember, other large cities that front on rivers or lakes have never had to worry about their water supply. The city of New York had the greatest problem and yet she never went more than 120 miles and there were no mountains to climb. It all came by gravity. She is the only city that had any great water problem; the others just dipped their suction pipes into the rivers or lakes.

You gentlemen are required to contemplate in your every day business, greater problems than any city in the east; you have a more extensive job before you.

The city of Los Angeles is peculiarly situated; the great area to the north of it; the San Fernando Valley is being very rapidly settled; it was used as the dumping ground for the Owens River water pending its need for domestic use, and was used there temporarily until we should know what to do with it.

Our storage facilities for this supply in the San Fernando Valley were too far removed from the city proper for safety, and provision was made for additional storage closer to the city, on the margin of the Santa Monica Mountains, where we now have a storage free from any risk of interruptions. These reservoirs are very capacious, having an average capacity of 30,000 acre feet with supply mains running right into the city.

The insurance companies used to wonder how we were going to safeguard our water supply. There is not a city in America whose water supply is so completely safeguarded against interruptions. Why? Because it was built with that end in view. We have thirteen mains leading into the city and do not depend upon any one main carrying water from a remote source of supply. I am not taking any particular credit; however, my organization is to be thanked for it. The thing seemed to be suggested naturally and it was so built. I think it is the Bible or the Koran or other high religious authority that said: "He who bloweth not his own bazzoon the same shall not be blown."

The new project embraces the territory lying between the Colorado River and the Pacific Ocean southerly of the Boulder Canyon Dam site. The ostensible first route was surveyed for the aqueduct to convey water from the Colorado River. Since we started on the surveys for this route we resolved not alone to survey that line but the potentialities and possibilities of other directions to get a cheaper line. We started broadcasting and within certain boundaries, including the entire Boulder Dam Country clear over to the Grand Canyon of the Colorado, we closely surveyed every bit of the area and it will be shown in our complete topographical map. This entire country is worked out into a model relief map so that we can stand in front of that map and plot any route without leaving our office. Every bit of it has been traced mile by mile. We found out where tunnels and siphons will have to be built and where the ground is too high or too low. It is the most monumental piece of work of its kind ever constructed and is within a month of being completed.

The direct route from Blythe to Los Angeles is the one that requires the least tunnelling; it is the one that comes out with the higher point of delivery. I will not deny the fact that I am in favor of that route. I do not like to boast about the discovery, but if you turn a jack-rabbit loose at the Colorado River and head it for Los Angeles, and scare him enough, he would go via that route.

The Governor of this State, shortly before election, announced that he and his engineers had discovered a shorter route for the Colorado River Aqueduct. I do not know how he found it up there in his office at Sacramento. Neither have I been able to verify such statement from his engineers. On the contrary these gentlemen, whom I know well, spent ten or twelve days with me all over that desert country and have informed me that they made no such claims.

We can take our map and draw a line along any route that may be proposed by a normal person, as a substitute for the route we have. We did that to guide the people in their judgment and estimation of our ability to lay out the line. If they can find any way that this line can be shortened, decreased in cost, or increased in efficiency, we are willing to let them do it that way and the map will be before them.

I think it is a great thing that the city of Los Angeles has not been discouraged by the shortage of the Owens River Aqueduct supply (due to the prolonged drouth affecting the entire coast area), but have turned to this new project.

The Los Angeles Aqueduct cost us a bond issue of $153.00 per capita. We had at that time 160,000 people in the city of Los Angeles. Now that did not scare the people. They went to the bat and built the aqueduct receiving their benefit in the shape of billions of dollars in increased value to the real property alone, which paid for the aqueduct many times over. That debt is a little over one-third paid off at this time and we are going to undertake another debt. The estimated cost, in the rough, is between $150,000,000.00 and $200,000,000.00. It will not cost as much per capita as the

Owens River Aqueduct. The city is proportionately larger than it was then so it is therefore not a great undertaking.

I reasoned these things out—soothed myself. I am itchy about it. I am afraid to talk about that much money as I was brought up by frugal people in Ireland and there was not that much money in all Ireland I am sure. At any rate, it will be about that sum and I do not think the people need fear to incur the debt, nor do I believe the people will have any such fears.

The people of Los Angeles are a canny kind of folk but where they can see a profit they are going to invest—you can depend upon that.

San Francisco is a city for which I have always had great admiration in every way. She has been burned up; shaken up; and the people turned to and rebuilt her within a couple of years and then turned around and staged a fair the equal of anything in the world. But there is something about her not the same as Los Angeles. She is not a practical city; the people cavil and do not get together on material things. They undertook the Hetch-Hetchy—there is something providential about the city of San Francisco—there is something that seems to look after her. She has never suffered a water famine and some of us who know about the water works condition of that city, marvel how the water works men of that city can go to bed nights and sleep; they have been on the verge of disaster for several years. They have a wonderful project in San Francisco, the Hetch-Hetchy. I have often wondered why they do not call it the Itch-Itchy because they have been scratching themselves about it for thirty years. As a matter of fact they began work on it ten years before Los Angeles undertook the construction of the Owens River Aqueduct. They can remedy that; they are proud, fine people and many of them who hear my remarks tonight will no doubt write me very indignant letters, but I am telling you what is the truth, that the people of the city of Los Angeles are not that kind. They do not compare in many ways in romanticism or chivalry with the people of San Francisco, but they can get together and do a job of work,—just authorize them to do it.

THE CLEVELAND RESERVOIR[1]

By Elbert Peets[2]

Our drinking water, in Cleveland, is stored in a covered reservoir. The reservoir keeps the water clear and cool, and to do that as effectively and economically as possible is its only reason for existing. Quite incidentally, it is an architectural masterpiece.

It is called the Baldwin Reservoir. (Actually there are two, but I shall use the singular number because they are exactly alike.) It is a subterranean room about five hundred feet square, surrounded by concrete walls, paved with concrete and covered with a roof of intersecting flattened barrel-vaults of concrete carried on round concrete piers. The crown of the vaults is forty feet above the floor. The piers, which are thirty inches thick, are about twenty feet apart both ways. The only openings are a few small manholes in the ceiling.

The beauty of the Great Hall of Cleveland is first of all in its vast extent—its six hundred columns, its fifty aisles. But it has delicacy, too. The aisles are pleasantly proportioned in cross section. The columns are spread conically at the floor, an unpleasant shape but at a distance softening into a simplified diagram of an architectural column base. At the top there is a rather bungling transition from round to square to meet the square springing of the vaults, but here again, with almost pathetic lack of affectation, the aesthetic function of a capital is expressed.

There is nothing quite like it anywhere. Each aisle has about the proportions of the side aisles of a moderately high Gothic church, Winchester Cathedral for example, though the flattened vaults remind one of later Gothic buildings such as St. George's Chapel, Windsor. But for the great area, the forest of equispaced columns, the precedents are ancient. That is a hot-climate, Mediterranean idea. The great hall in the temple of Ammon at Karnak was 160 by 320 feet and contained 134 columns. The Hall of a Hundred Columns at

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[1] Reprinted by permission from "The Nation," February 9, 1927.

[2] Architect, Co-author with Werner Hageman of "Civic Art."

Persepolis had just a quarter the area of the Cleveland hall, but its ceiling was twenty feet higher.

For the "public inspection" in 1925, before the reservoir was flooded, a few aisles along the west wall were lit by hanging an electric bulb close to the ceiling in every fourth or fifth bay. The rest of the hall was dark save for a few "Jove's eyes" where manholes had been left open. The warm yellowish electric light spread out from each of the lit bays and laid a net of radiating column shadows on the floor. The curved shapes of the springing vaults, caught by the shadows of the vaults nearer the lights, produced a fantastic mosaic of interwoven spots and lines varying from bright gold through every shade of warm gray to deep soft black. The columns were halved and quartered by the shadows of other columns or were picked out of the darkness by narrow tangent strips of light.

In search of new aspects I wandered out from the lit bays into the dark forest of columns. A dozen bays deep in it, when I looked back along an aisle I saw a bluntly bullet-shaped area of warm gray concrete wall, streaked with vertical shadows and framed by the lighter lines of the more directly lit columns near it. Nearer me the columns became less and less light. There was a similar gradation of light in the ceiling, not uniform but flecked with light and dark as rays or shadows caught the surfaces of the groined vault. Across the bottom of this deep stage-setting moved a line of little people silhouetted against the bright wall, so far away that I could not hear their voices or tell whether they were looking out into the darkness toward me.

Another fine view was from north to south along a dark aisle in which there was an open manhole in the top of the last bay. Everything around me was jet black. In the distance again the bullet shape, this time not of warm light but cool silver, the white light streaming down through the manhole and along the gray columns, spreading out on the floor to form a white line from one base to the other.

The view which had most of "art" in it was a concrete stand-pipe, seen from about two hundred feet away, along the aisle in which it stood. The front of the enormous pipe was lit by an open manhole just above it. The white light flooded down along the gray cylinder, broken only by the black drooping shadow under a flange-offset ten feet from the top. Each side of the cylinder darkened into shadow, but just at the turning was a pale line of ruddy light from the electric bulbs. On the floor some ponderous valve-affair served as altar and a dark crowd of pigmy worshipers stood with heads uplifted as the high-priest chanted "Ten million cubic feet, two million dollars." . . . . Everywhere I was surrounded by a star or diagonal vistas, narrower, more sharply crowned, more Gothic than the full views down the aisles.

No architect ever lived who would not stand in silent wonder in this Hall of Six Hundred Columns. It is an abstraction, a song in some nameless mother-language that everyone understands. It is the work of a law, of a formula ruling over space and mass—rather, perhaps, a law brought into the range of our feelings by being stated in the most fundamental, most simple terms of human need for formal perfection. It is the product of man's desire for order, freed from the old conventions of architecture by the new conventions of engineering.

The great beauty of the reservoir is its simplicity and purity. Nothing is petty, nothing is irrelevant, nothing is boastful, nothing tells a story, nothing mumbles the names of gods, men, or races—nothing is human. There are no windows, no doors, almost no light, no sign of human use, not even a stone cut small so men could lift it. And yet it is superbly human. Besides it the formless jumble of nature becomes a congeries of wilful antics. It is so human that in an hour it became very dear to me. Its floor's level firmness gives my body the safest and most assuring relation to the earth; the solid ceiling, curving from pier to pier, does not weigh upon me and yet protects me from all the unknown things of the air. The strong round columns seem human, make me feel taller and stronger. My eye follows them as they march away into the shadow and I actually touch and measure and embrace the space that surrounds me. I live at last in a cosmos.

And we built it to cool our drinking water.

THE BALDWIN FILTRATION PLANT[1]

By G. W. Hamlin[2]

The placing in operation of Baldwin Filtration Plant, in the fall of 1925, marked the beginning of supplying all filtered water to the entire district served by the Cleveland Water Department. Prior to this time only a little more than one-half of the entire water supply was filtered at the Division Filtration Plant.

In describing this part of Cleveland's water system, it will be convenient to divide it into four parts, first, the supply of water from the lake; second, the filtration plant proper; third, the storage of filtered water; and fourth, the supply of filtered water to the distribution system.

SUPPLY OF WATER FROM THE LAKE

The water filtered at the Baldwin Plant is obtained from a steel intake crib, located at the end of the Kirtland Pumping Station tunnel, and about four miles off shore. From the intake it flows through a nine foot circular brick lined tunnel 26,047 feet long, to the suction wells of the Kirtland Station pumps. These pumps force the water to Fairmount Reservoir, a former supply reservoir, located at a lower elevation than, and just west of, the filtration plant.

Prior to the construction of Baldwin Filtration Plant, Fairmount Reservoir was used as a supply reservoir floating on the low service district. Accordingly, only a part of the water pumped from Kirtland Station reached the reservoir, as branch mains tapped the feeder mains on the way.

The new plan provided for the replacement of this reservoir by a larger one at a higher elevation, and the use of Fairmount Reservoir as an intermediate storage reservoir for raw water, between the lake and filter plant. The Kirtland Station pumps were to deliver water to this reservoir and then it was to be repumped to the filter plant by low lift pumps in the new Fairmount Pumping Station.

The new use of the reservoir required rearrangement of the mains leading from the reservoir and rearrangement and increase of main capacity leading from Kirtland Station.

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[1] Presented before the Central States Section meeting, September 21, 1926.

[2] Engineer of Construction, Water Department, Cleveland, Ohio.

By cutting out their connections to branch mains, use was made of three existing 48-inch mains to carry the raw water part of the way to the reservoir, and a new 48-inch main was built from the station for a part of the way. From the ends of the four 48-inch mains, two new 60-inch steel mains were laid the balance of the distance to the reservoir.

At the reservoir new control works were provided. Two inlet gate houses, with submerged discharge into each half of the reservoir, were provided to receive the discharge from the two new 60-inch mains.

An outlet gate house was built in each half of the reservoir to control the supply of water to the new Fairmount Pumping Station. Water was taken into these gate houses through screened openings which were connected by shaft and tunnel with the suction header under the low lift pumps.

Lake water is drawn from Fairmount Reservoir by three turbine driven centrifugal pumps, located in the new Fairmount Pumping Station, and forced to the rising well in the chemical house at the filtration plant. Two of these pumps deliver 75 m.g.d. each, against an 86-foot head, and the third delivers 50 m.g.d. against the same head.

THE FILTRATION PLANT

Baldwin Filtration Plant is located on a fifty acre plot of ground lying between Fairmount Road, on the north, Woodstock Avenue, on the south, East Boulevard on the east, and Baldwin Road on the west. All parts of the plant were designed and constructed to filter 165 m.g.d. which was the maximum capacity of the existing tunnel and intake at Kirtland Pumping Station.

The description of the filter plant may be conveniently divided into the following four subdivisions: the alum storage house; the chemical house and hydraulic jump mixing flume; the coagulation basins and the filters and administration building.

Alum storage house

Due to the location of the filtration plant a considerable distance above and off the line of the nearest railroad, it was impossible to maintain a permanent railroad connection for the delivery of chemicals. This necessitated the construction of an alum storage house at the nearest railroad siding, and the trucking of alum from this storage house to the smaller storage bins in the chemical house at the filter plant.

The alum storage building is located along a railroad siding, on a plot of ground adjacent to, and just south of, the grounds of the new Fairmount Pumping Station. The building is of reinforced concrete construction faced with brick. It is 86 feet 8 inches by 50 feet 10 inches in plan, with a covered extension over the unloading hopper and railroad siding.

The building is divided into two general floor levels, the one at ground level containing truck runways beneath the storage bins, and the other forming the tops of the bins, upon which are located the screw conveyors for distributing alum.

Alum is delivered to the tracks under the covered extension, to the north of the building in box cars. It is unloaded by a plow operating inside the car, to a counterweighted chute leading from beneath the car door to a hopper, which feeds onto an apron conveyor. The apron conveyor takes the alum a short distance to a roll crusher.

Here it may be crushed and fed onto a bucket conveyor, or bypassed to the bucket conveyor without crushing. The bucket conveyor lifts the alum to the top floor of the building and across to any one of the three screw conveyors running longitudinally of the building over each one of the three rows of storage bins. Each of the screw conveyors discharges into any one of four bins. The total capacity of the twelve storage bins is 1000 tons of alum. The unloading and alum handling equipment was designed to handle alum at the rate of twenty tons per hour.

As alum is needed at the chemical house, a dump body motor truck may be driven under the bin gate at the bottom of the storage hopper and the truck filled with alum. Paved driveways are provided along both sides of the storage building, and openings, closed with steel rolling doors, are provided so the truck may move across the building under any one of four rows of storage bins. The doorways are arranged opposite each other so the truck may enter at one side of the building and leave at the other.

Chemical house and hydraulic jump mixing flume.

The chemical house is located midway along the southerly boundary of the plant. The building is divided into three general floor levels above and one floor level below ground.

The receiving room for alum is located at ground level at the west end of the building. Here a large double door provides entrance for the truck delivering alum. Alum is dumped from the truck through manhole openings in the floor into the storage bins located directly beneath. It may be drawn from the storage bins through a chute located at the bin bottom and controlled by a gate.

Underneath the lowest part of the bins a tunnel has been provided into which the chutes from the bins project. A narrow gauge track runs the length of this tunnel. Mounted upon this track is a narrow gauge flat car, upon which may be placed a circular, bottom dump, alum bucket. When drawing alum, the flat car and bucket are pushed beneath the chute leading from the bin, from which alum is to be drawn. Alum is then drawn through the gate into the bucket. The car with the loaded bucket is then moved along the track, turned on a turntable, and moved into the hoisting shaft.

In the top floor of the chemical house are located the openings into six alum dissolving tanks in which the alum is dissolved by an upward flow of water. Alum is moved from the bottom of the hoisting shaft to the top floor level by means of a motor operated hoist. This hoist is mounted on a carriage traveling on a monorail, suspended from the lower chord of the roof trusses. This monorail leads from the hoisting well to a position over each one of the dissolving tanks, so the alum in the bottom dump bucket may be discharged directly into the dissolving tanks.

The alum solution flows directly from the dissolving tanks to solution tanks located just east of them. There are four solution tanks. The dissolving and solution tanks are arranged in two groups, one group on either side of the center of the building and the tanks in each group are interconnected so that alum solution from any one of three dissolving tanks may be discharged into either one of two solution tanks. On the next floor below are located the orifice boxes for controlling the rate of flow of alum solution. Gravity flow of the alum solution is obtained from the dissolving tanks through the solution tanks and orifice boxes to the point of application to the water in the rising well.

The water to be filtered is discharged from the two 60-inch mains leading from the low lift pumps at the pumping station into the rising well, which is ten feet wide and extends across the entire width of the chemical house. From the rising well the flow is through a wide shallow channel to the entrance of each of the three parallel hydraulic jump mixing flumes. These take the place of the usual baffled mixing channel.

From the mixing flume the water passes through two sets of over and under baffles and is delivered at No. 1 Gate House, at the southwest corner of the coagulation basins.

Coagulation basins

The four coagulation basins are located lengthwise along the east end of the filtered water reservoir. Across the south end of the basins, and running parallel to Woodstock Avenue, is the influent conduit with gate houses numbered one to three inclusive, controlling the flow of water into the different basins.

Along the north end of the basins is the effluent conduit with gate houses, numbered four to six inclusive, controlling the flow of water out of the basins. Along the west side of the basins and between them and the reservoir is located a conduit connecting gate houses one and six. By the proper manipulation of sluice gates, the entire flow of water may be bypassed around the coagulation basins and through this conduit.

The water is introduced into each basin over a submerged weir extending the full width of the basin and is drawn off over a similar weir at the other end of the basin.

Each basin is provided with a longitudinal drain running through its center under the floor for almost the full length. Due to the shale foundation upon which the basins are constructed, it was possible to make the floor pitch sharply to this drain, without undermining the wall foundations. This facilitates the removal of sludge, and still keeps the dividing and outside walls of a low height, thus cheapening construction cost as the height of the walls is only about one half of the total depth of the basins.

Each basin is $109\frac{6}{10}$ feet wide and $661\frac{1}{2}$ feet long between influent and effluent weirs, with an area of water surface of about seventy three thousand square feet and volume of eight million two hundred thousand gallons. The maximum water depth is $18\frac{1}{2}$ feet, with a minimum of $9\frac{3}{10}$ feet, and an average of $14\frac{9}{10}$ feet.

At full capacity of the plant the velocity of flow is $2\frac{36}{100}$ feet per minute, with a detention period of four hours and forty minutes.

Filters and Administration Building

The forty rapid sand filters are located along the north side of the reservoir. They are arranged symmetrically about a large well lighted central pipe gallery, the cover of which forms the floor of the operating gallery, which is at the same level as the tops of the filter tanks. At the center, the administration building divides this long double row of filters into two sections.

The operating gallery is covered by a high roof supported on walls vertically above the front line of the filters and bearing on concrete beams forming a part of the roof covering over the filters. The roof over the filters is of concrete, and of sufficient height to provide ample clearance for walking upon the inspection walks over the tops of the filter tanks. These walks are at the same level as the operating gallery floor and provide ready means for observing washing of all parts of the filter surface.

Each filter is $33\frac{1}{2}$ by 49 feet inside measurements in plan, with an area of sand surface of 1450 square feet. The depth from the concrete floor of a filter to the top of the observation walks is $13\frac{1}{2}$ feet.

The strainer system placed on the floor of the filters is of the perforated pipe lateral and manifold type. The laterals are of cast iron, $2\frac{1}{2}$ inches in diameter and spaced 7 inches apart. They are drilled on their underside with $\frac{11}{32}$-inch diameter holes, spaced about $4\frac{1}{4}$ inches apart.

Each filter contains twenty two inches of graded gravel, placed in four layers and ranging from $1\frac{1}{2}$ inches to $\frac{1}{16}$ inch in size. On top of the gravel is 30 inches of sand, having an effective size of 0.38 of a millimeter.

The settled water flows from Gate House No. 6 to the administration building through a concrete conduit along the outside wall of the northeast effluent gallery. At the administration building the conduit makes a right angle turn and runs through it to a junction with the concrete distributing conduit running through the length of the pipe gallery. Cast iron pipe and fittings connect the filters with the concrete conduit.

Directly under the filters are located small filtered water reservoirs, which receive the discharge from the filter effluent lines. Each one of these effluent galleries is connected by a 54-inch pipe line with a central concrete filtered water conduit in the lower part of the administration building. This filtered water conduit terminates in a

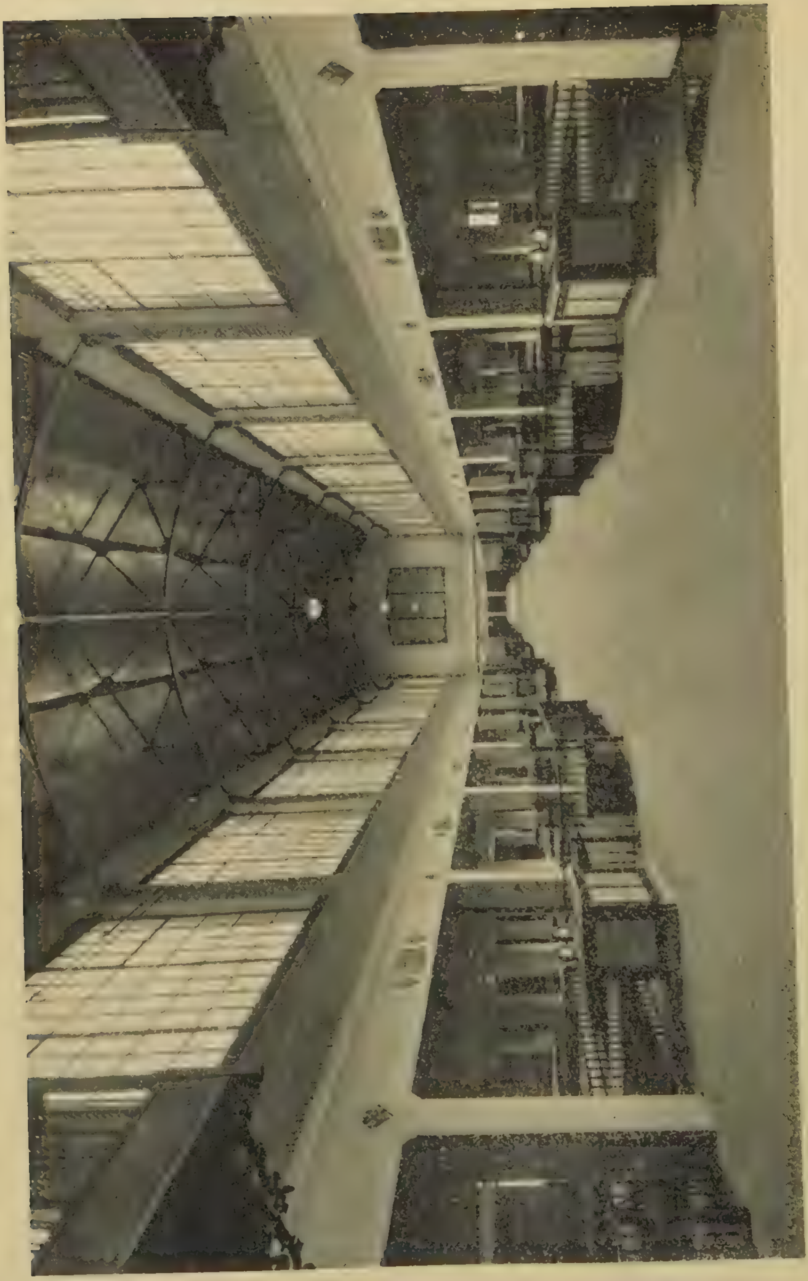

Fig. 1. West Operating Gallery, Baldwin Filtration Plant

forebay near the north wall of the reservoir, with sluice gates to control its discharge into either half of the reservoir.

All the filter valves, except the filtered water waste, are hydraulically operated and controlled from the bronze and marble operating tables, mounted on the floor of the operating gallery, at each filter.

Wash water is stored in two steel tanks, each 60 feet in diameter and 12 feet deep, located on the top floor of the administration building. The storage capacity of the two tanks, with 10 foot depth of water, is 423,000 gallons.

A common supply and discharge riser connects the two tanks with the wash water main in the pipe gallery, at a cross in the lower part of the administration building. The discharge pipe from the wash water pumps is also connected at this cross.

At the extreme west end of the wash water main in the west pipe gallery, connection is made with a 24-inch distribution main carrying water from the first high service reservoir. Thus two ways are available for filling the wash water tanks, by using water from this emergency connection, or by pumping from the special wash water pumps.

Four electrically operated wash water pumps, having a total capacity of fifteen million gallons daily, are located in a pump room adjacent to the lowest floor of the administration building. These pumps obtain their suction from either one of the two north effluent galleries.

Each one of the pumps is operated by a separate float in the wash water tanks.

Filtered water reservoir

The filtered water reservoir has a storage capacity of 135,800,000 gallons, and is the largest covered reservoir in the world. It is 1008 by 521 feet inside dimensions in plan, with a maximum water depth from lowest point of floor to overflow, of 36 feet. A dividing wall, parallel to the short dimension and located at the center of the long side, divides it into two basins, each about 500 feet square. The reservoir is constructed of concrete, with a concrete groined arch roof, supported by 1196 columns 30 inches in diameter, 34 feet, 3 inches high, and spaced 20 feet 3½ inches on centers.

Filtered water is discharged into the reservoir by means of a channel inside the reservoir, running practically the entire length of the north wall. At regular intervals along the side of this channel, weirs permit the overflow of water from the channel into the reservoir.

Water is collected for discharge from the reservoir by ports located near the floor level along the entire length of the south side. These ports lead to a conduit within the south wall, which connects with a conduit in the west wall, leading to Gate House No. 7. At this gate house double sets of valves control the flow of water to the distribution system.

This reservoir, in addition to being the clear well for the filter plant, also serves as a supply reservoir floating on the low service district.

SUPPLY OF FILTERED WATER TO THE DISTRIBUTION SYSTEM

Leading from Gate House No. 7 are seven mains. Two mains, 36 inches in diameter, and three, 48 inches in diameter, supply water to the low service district, and two, 48 inches in diameter, furnish water to the suction header of the first and second high service pumps at the new Fairmount Pumping Station.

In addition to the low lift pumps already mentioned, Fairmount Station contains the following turbine driven centrifugal pumps: two pumps to deliver water to the first high service reservoir, each one with a capacity of 20 m.g.d. against a 135 foot head. Three pumps to deliver water to the second high service reservoir, two with a capacity of 15 m.g.d. each and a third with a capacity of 20 m.g.d all against a 400 foot head. Each one of these two 15 m.g.d. pumps may be changed to 20 m.g.d. capacity by changing the runner in the turbine, thus giving an ultimate total second high service pumping capacity of 60 m.g.d.

Steam for operating these turbines is supplied at a pressure of 300 pounds at the throttle by four 1,000 H.P. Stirling boilers. Steam is bled from some of the turbines at 125 pounds pressure for supplying the municipal heating system.

The total cost of the filter plant alone exclusive of land and final landscaping, was $5,908,000.00, and of the reservoir $2,900,000.00, making a total of $8,808,000.00.

WATER TREATING PROBLEMS IN RAILROAD PRACTICE[1]

By S. C. Johnson[2]

The water treating problems encountered in railroad practice vary to some extent from those usually given consideration in municipal service. The bacteriological feature is generally considered of minor importance and the question of turbidity is subordinated to the influence of the scale forming or corrosive salts.

Although water supply is one of the prime essentials in the operation of a steam railroad, it is of interest to know that the details and problems, especially with regard to quality, were formerly given but minor consideration. In the building of railroads, the major interest was expended in the construction of the roadbed and the operation of trains. Nothing was said of water supply, if it was adequate and not too muddy and water stations were installed where necessity and expediency demanded. These facilities consisted merely of some means of supplying water to the engine tank for steam consumption. However, with the alleviation of construction problems, conditions changed and greater attention to possible economies has become necessary under the strict regulations which now govern the operation and financing of our railway properties.

The quality of the water supply is closely associated with the operating efficiency of a railroad and its result has a marked influence on the locomotive maintenance expense. Only recently two prominent railroads have undertaken the reorganization of their water supply department and instigated treatment based primarily on the remarkable savings made by such refinements on adjacent first class railroads.

Of the 350 billion gallons of water now being used annually for steam purposes on American railroads, it is estimated that 50 billion, or about 15 per cent are receiving treatment in some form. At a general average cost of 4 cents per 1000 gallons for treatment, the yearly operation expense is in the neighborhood of $2,000,000. There are approximately 1200 water stations out of a total of 16,000, where chemicals are added and the total investment in softening plants, including the inexpensive as well as the elaborate types, is at least $10,000,000. It is estimated that these plants are removing 100,000,000 pounds of scale forming solids annually, which, if allowed to enter the locomotive boilers, would represent an additional expense in locomotive operation and maintenance of approximately $13,000,000.

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[1] Presented before the Boiler Feed Water Studies Committee Session, Buffalo Convention, June 9, 1926.

[2] Chief Chemist, Water Supply Department, Chesapeake and Ohio Railway, Huntington, W. Va.

There has been no detailed general survey made to show the sources of railway water supply. However, in Water Supply Paper 496, of the United States Geological Survey, a classification of 307 water supplies from the principal cities of the United States indicates that 234 were obtained from surface waters and 73 from wells. This ratio will probably hold true to a large extent in railroad service.

The properties in water which cause trouble in stationary power plants are of similar concern in locomotive practice, although the refinements are not, as yet, applicable. The chief concern seems to be the non-carbonate scale which causes damage by forming hard cement-like coating on the heating surfaces with consequent deterioration of the material and fuel loss. The carbonates of calcium and magnesium are troublesome when present in large quantity, due either to increasing the bulk of the scale or precipitate. Waters containing mineral acids or with low pH values are occasionally encountered which initiate pitting and corrosion troubles if not corrected. In some parts of the country, particularly that section commonly known as the alkali plains, it is necessary to use waters high in alkali salts, principally sodium sulphate, which not only aggravates the foaming tendency of the waters, but also contributes to an electrolytic condition which accentuates pitting and corrosion unless counteracted. It is possible that siliceous matter has entered into the scale problems in some quarters, but the complaints from this possibility have been of minor importance and it is only within a recent period that serious consideration has been given to the elimination of mud and suspended matter.

The development of water treatment on American railroads has received its greatest attention on middle western systems where the objectionable quality of the natural waters was such that some form of treatment early became an operating necessity. Possibly, because of practicability, or lack of research work or information on this subject, efforts toward correction were confined at first to internal treatment, principally with so called "boiler compounds" or "metal treatment" with secret formulae. Where conscientious attention was given the troubles were somewhat alleviated, especially with waters of the more moderate hardness, but unscrupulous competition developed with "mystery" products of but little value which cast serious reflection on this method in many quarters. It was therefore found advisable by many railroads to find some more thorough and systematic means of handling, although internal treatment with compounds, applied either directly to the locomotive or in wayside tanks, is still giving good service where they are being handled under intelligent and careful supervision.

The next development in counteracting the harmful impurities was in the application of soda ash, both direct in the boiler or at wayside tanks. The scale reduction properties of this material are well known and this appears to be the least expensive systematic treatment from a first cost standpoint. However, the precipitate formed by this reaction is so finely divided that the sludge in the boilers, together with the increase in alkali salt concentration, causes serious foaming conditions and the system has been found objectionable unless followed up with careful supervision to insure the boilers being blown down sufficiently to maintain the concentration within workable limits.

The systematic treatment with soda ash at wayside tanks appears first to have been developed on the C. B. & Q. R. R. and later extended to the Wabash, Frisco and the Alton. Several other roads are using it to some extent. The method consists in treating all waters, where necessary, to insure an excess of about two grains per gallon sodium carbonate. Frequent check is made of samples from locomotive boilers and effort is made to maintain approximately 15 per cent of the total dissolved solids as sodium carbonate. This internal inspection is also necessary to insure sufficiently frequent blowing to keep the total dissolved solids below 125 grains per gallon in order to prevent foaming delays. Where sufficient supervision is provided to insure the carrying out of the predetermined practice, very satisfactory results have been secured. However, the necessity for the careful check and follow-up of the locomotive operation presents such difficulties that the extension of this system has been somewhat limited.

Experiments with zeolite softening for railway service have not been altogether satisfactory, although tests being made at the present time on the western coast indicate possible success with certain types of waters. The preponderance of surface supplies, with their occasional high content of suspended matter, limit the scope of this system as well as the dissolved solids quality, unless prefiltration is provided, with additional expense for installation and maintenance.

The standard and usual method of complete railway water softening now practiced consists in the addition of lime and soda ash to the water in predetermined amounts at wayside settling tanks. Its object is not only to soften the water, but also to remove the precipitated sludge with mud or suspended matter, so as to deliver the waters to the boilers not only soft but clean.

The lime and soda process of treatment in railway service has developed from the simple intermittent system which consisted merely of two or more tanks which were filled, treated and used alternately, through the intricate proportioning devices with continuous automatic proportioning, back to the more sensible and simple continuous systems. The chief essentials are proper chemical proportioning and sufficient mixing and reaction time followed by sedimentation and clarification before delivery of water for use.

Many intermittent systems are still in use and the capacity of treating tanks varies from 10,000 to 500,000 gallons, but the governing principle is the same and similar satisfactory results can be secured. The usual means of agitation is by compressed air, which is a more flexible and more easily maintained system than the mechanical agitators which have been tried.

Plants of the continuous type consist of large tanks, usually of steel, with inside tubes of sufficient size to retain the water during the mixing and reaction period of from 30 to 45 minutes. The water and chemicals are mixed in these tubes in continuous proportion, flowing from the mixing tube to the bottom of the sedimentation tank from which they rise to a predetermined point before the clear water is drawn off for service. The specific gravity of the precipitated sludge is sufficiently greater than water to permit complete clarification in five hours, if the vertical velocity of the settling water does not exceed 8 feet per hour, provided, of course, that the proper amount of chemicals have been added to insure complete reaction and unbalanced equilibrium avoided. If clarification troubles are experienced, filters are sometimes provided which usually consist of matted excelsior at the top of the sedimentation tank, although there are a number of plants in service with gravity or pressure sand filters. Some experimenting is again being done with the elimination of the downtake tube and merely running the chemicals and water together without special mixing or agitation at the bottom of the sedimentation tank, although experience with this system some years ago was not entirely satisfactory.

In any system of water softening for railroads, the largest single factor in securing satisfactory results lies in competent and interested supervision. The chemical quality of the raw and softened water should not only be checked at frequent intervals, but inspection should also be made of the mechanical facilities to insure dependable and uninterrupted service. On railroads where treatment is practiced to any appreciable extent, systematic methods are therefore necessary to permit the situation being handled with minimum force. An outline of the rapid methods for field work and laboratory testing was given on pages 107 to 115 inclusive of the August, 1925, Journal of This Association and these methods are largely a duplicate of those which have been found satisfactory and adopted as standard recommended practice by the American Railway Engineering Association.

The savings which are possible through improvement in quality of railroad water supplies are necessarily dependent upon local conditions In 1914, the American Railway Engineering Association presented figures to show that the cost of each pound of incrusting matter permitted to enter the locomotive boiler, in such condition that it would deposit as scale on the tubes and sheets, was 7 cents, considering only the effect on fuel consumption, boiler and roundhouse repairs and engine time. This figure, transposed to present day prices, is 13 cents. Study by a special committee of the American Railway Engineering Association for the past five years has found that the statistics which have been gathered indicate that this figure is conservative. There is no question but that, with proper treatment of the water, scale and pitting conditions, with their incident boiler maintenance expense, can be largely eliminated and that the fuel consumption in clean and dry boilers is much less than with leaky or badly scaled power. In addition, the large intangible benefits, such as elimination of engine failures on the road and the reduction in delays to traffic and train movements, usually far outweigh the tangible savings in fuel consumption and boiler repairs. However, each individual case is a problem in itself and requires special study in order to obtain best results.

On the Chesapeake and Ohio Railway, during 1925, there were 30 water softening plants in service at the 207 water stations. Of these 30 plants, 23 were of the continuous type, 2 intermittent, and 5 of the simple soda ash system. Of the 6,135,922,000 gallons of water used for steam purposes, 2,496,038,000 gallons, or 40.7 per cent were, treated and a total of 2,672,080 pounds of injurious scaling and corrosive matter removed before the water was delivered for steam boiler use. The total cost for chemical treatment, including operation, maintenance, interest and depreciation, was $103,715 or an average of 4.5 cents per 1000 gallons, but the cost for chemicals alone only averaged 1.98 cents. The estimated net saving for the year by reason of this treatment amounted to $243,675 which represents 67.2 per cent on the $356,323 amount invested in water treating facilities. This estimated saving averages but $480.00 per locomotive using the treated water, which is a conservative rating.

The wide range of the problem of water treatment, including the design and installation of plants, as well as the individual studies of the water quality and the check of the actual treatment and its effect upon transportation and train movement, well warrants the special study which is being given to it on many roads. In the handling of this problem over the wide range of territory involved on even the smaller railway systems, it is necessary to have the closest coöperation between the chemical supervision and the men actually operating and maintaining the plants, as well as the interest and assistance of the motive power and transportation departments, to secure the best, or even passable, results. The best mechanical facilities will function only in a perfunctory manner or fail entirely, if not followed up by a careful check system, it has been found that an organization with a definitely fixed responsibility is the first essential to successful results from railway water treatment.

MISSOURI HIGHWAY SANITATION PROBLEMS AND PROGRAM[1]

By W. Scott Johnson[2]

The need of proper sanitation along our public highways is developing in importance very rapidly as a result of the more general use of automobiles for transportation and the increase in hard surfaced roads. Supervision of the design and maintenance of public water supplies and sewerage systems has been recognized as necessary by state health departments for some time. The present increasing tendency for our population to move countryward along improved highways automatically imposes city sanitation problems upon rural conditions, and a program having for its purpose supervision of highway sanitation is necessary for reasons similar to those applicable to urban conditions.

It is the purpose of this paper to discuss the problem of highway sanitation in Missouri and the program for supervision which has been initiated by the State Board of Health.

GROWTH OF HIGHWAY TRAFFIC

The extent and importance of the problem of highway sanitation is necessarily closely associated with and in fact dependent upon the density of highway traffic.

The factors governing the growth of highway traffic are, first, number of automobiles in use, and second, the extent and character of highways available. Brief consideration of these two factors indicates several pertinent facts with regard to the growing popularity of travel by automobile and the increase in what might be termed highway population. The ability of the American people to buy automobiles has shown material increase in the last few years. Regardless of the fact that there is today one car to every six or seven persons in this country, recent estimates as high as forty million automobiles, or double the present number, have been prophesied as the future saturation point. In Missouri during the last five years, the number of cars in operation has more than doubled, from 297,000 to 602,000. Available information indicates not only a remarkable increase in automobiles the last few years, but still further increase over the present high figure as cars become more practical and necessary from an economic standpoint.

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[1] Presented before the Iowa Section meeting, November 3, 1926.

[2] Chief Sanitary Engineer, State Board of Health, Jefferson City, Mo.

The extent and character of highways is a factor in highway travel that can be more easily determined in that certain programs and plans are being followed. Last year there was constructed about 30,000 miles of surfaced road in this country. In the past five years 3700 miles of hard surfaced roads have been constructed on the Missouri state system, or six times the previous mileage. The present Missouri highway program calls for the completion of 7640 miles of hard surfaced road, of which 4200 miles are complete. In 1921 automobile travel in this state on hard surfaced roads was practically limited to small areas surrounding the larger cities. Today the state is well started on a program for a complete highway system.

The effect of more automobiles and increasing hard surfaced road mileage has already produced a marked change on travel by automobile. Travel by highway is rapidly developing from a seasonal, uncertain and hazardous adventure into an all year, dependable, and safe means of transportation. The rapidity and extensiveness of this means of transportation have progressed until it ranks among the first, regardless of the fact that it is still in the early stages of development.

Thousands of foreign cars enter Missouri each year especially during the summer months. These out of state travelers spend millions of dollars each year during their visit to this state. Particularly important from the sanitary standpoint is the fact that a large per cent of these tourists spend many days in camps along the highways. Another index of the popularity of highway travel is shown by the total average number of persons which are daily traveling these routes. Considering the improved highways, the State Highway Commission counts show an average of from 1200 to 15000 people daily traveling these roads exclusive of the greater numbers in the immediate vicinity of the larger cities. On the main highways, the population each day equals that of a fair sized city and during the tourist season these lanes of travel are actually becoming the homes of thousands of people day and night.

SANITATION PROBLEM

The growing popularity of highway travel is resulting in a redistribution of population away from the sanitary environment of cities into the open country, where knowledge of sanitation is meager and its practice almost unknown. This large moving population on the highways is restricted to the comparatively limited area of these lanes of travel. This area will seldom exceed the bounds of the highways, tourist camps and towns located along the highways. The length of time spent in Missouri will vary from a few hours in the case of through travelers to many days or weeks in the case of visitors, which have come to take advantage of vacation opportunities offered in many parts of the state.

The history of disease outbreaks and their control has demonstrated that the occurrence of most serious epidemics of diseases have been associated with the movement of people due to political changes or development of new, more rapid and extensive means of transportation. These epidemics of communicable diseases have been most difficult to control and have wrought the greatest distress. The present system of quarantine at ports of entry into this country has been devised as a necessary means of preventing contagious diseases being brought to this country through lanes of travel from foreign countries.

The dangerous possibilities of communicating diseases from place to place by automobile travel is readily apparent when one stops to consider the freedom with which autoists from all parts of the country use the highways for travel and the method of transmission of contagious diseases of the filth-borne type.

The highway tourists today may hail from any place on the North America continent, and represent practically every class of people from hobo to multi-millionaire. They may be coming from localities recently infected by disease and are possibly, unknown to themselves, carriers of diseases. At present no restrictions, such as compulsory registration, medical examination, detention, or other similar check, are placed upon tourists passing from one state into another. In fact, one may frequently pass from one state to another without knowledge of the change. Consequently, there is no way by which the citizens of a state or locality are protected from invasion by tourists who may transmit dangerous diseases.

On the other hand, a tourist is a guest in the state and as mentioned before a most profitable one. Unacquainted with local conditions this stranger may consume water from contaminated sources and contract typhoid fever or other contagious diseases. As a guest and one whom we have good reason to welcome, the tourist should be protected in every way possible against contracting diseases and leave the state or locality a booster and not a knocker.

The spread of diseases of the filth-borne type comes about through the germs being transmitted from sick to well persons by means of food and drink. Carelessness or ignorance in the proper disposal of excreta results in the germs causing typhoid fever, colitis, dysentery, diarrhea and enteritis being washed into unprotected drinking water supplies or carried to food or drink by flies and other insects. As the number of people traveling the restricted area of the highways increases, the dangers from filth-borne diseases increase to a corresponding degree unless sanitary toilets and pure water supplies properly protected from pollution are provided along the highways.

The highway tourist requires water that is cold, clear and pleasant to the taste, giving no thought to its source or possible pollution. The average city inhabitant has become accustomed to safe water supplies and sanitary sewage disposal being provided by a convenient method and without individual responsibility or concern. This promotes a false sense of security with regard to any convenient water supply. Unfortunately, either through thoughtlessness, ignorance or lack of consideration, a large number of people have slight regard for the possible pollution of a water supply for the next person, as long as their own immediate needs have been satisfied. Consequently, the proper sanitation of our highways involves not only safe water supplies and sanitary toilets at convenient intervals along the high ways, but adequate designation and proper maintenance of these, if the permanent citizens of the communities which come in contact with tourists are to be protected and if the tourist is to be protected against contraction of diseases while passing through or visiting a state. It seems opportune that the question of highway sanitation should be inaugurated at this time in Missouri, when the volume of highway traffic is expanding due to the increase in automobiles and the near completion of the highway system. Thus it is hoped to avoid any disastrous epidemics, and provide for proper sanitation before an outbreak of disease has occurred from this source.

PROGRAM FOR MISSOURI

The health protection, comfort and convenience of the highway population should be the aim of an adequate plan of highway sanitation. The problem is statewide in its scope and therefore should come under the jurisdiction of state agencies. The Missouri State Board of Health and the Missouri Highway Commission are cooperating on a plan to establish comfort stations at frequent intervals along the state highways, the same to be indicated by a special highway sign. Many features of this plan are not original. However, it seems well adapted for securing improved highway sanitation in Missouri for the following reasons: safe drinking water supplies are provided along the highways at frequent intervals, protected from contamination; sanitary toilets conveniently located are provided; permanent, conspicuous and standard markings indicate comfort stations; comfort stations are owned and operated largely by private individuals, who are vitally interested in their proper upkeep; the program is not negative in character, since it is the satisfactory comfort station which receives the approval. This feature simplifies the supervision and gives a service of a positive nature to the highway travelers that meets with greater approval than one of prohibition.

In order that the comfort stations be properly equipped in a sanitary manner with a view to the convenience of the autoists as well as the sanitation of the highways, the following specifications have been formulated.

GRADE A COMFORT STATION

Water Supply

1. All grade A comfort stations shall have conveniently available a safe drinking water supply free from sanitary defects and conforming to the standards of the United States Public Health Service.
2. Individual paper drinking cups shall be provided.
3. No common drinking cup or glass shall be permitted.

Toilets

1. Two toilet rooms shall be provided, separate for men and women.
2. A minimum of one each of the following plumbing fixtures shall be provided for each toilet:

a. Water closet bowl with impervious seat and closet tank.

b. White enamel wash basins; an improved liquid or powdered soap container.

c. Suitable holder for individual or paper towels and receptacle for used towels. No common towel shall be permitted.

3. The sewage shall be disposed of in a sanitary and approved manner.

4. The building and fixtures shall be kept clean and sanitary at all times.

GRADE B COMFORT STATION

Water Supply

1. All Grade B comfort stations shall have conveniently available a safe drinking water supply free from sanitary defects conforming to the standards of the United States Public Health Service.
2. Individual paper drinking cups shall be provided.
3. No common drinking cup or glass shall be permitted.

Toilets

1. Two indoor toilet rooms shall be provided, separate for men and women.
2. A minimum of one chemical toilet shall be provided for each toilet room.
3. A wash basin, supply of water, an approved liquid or powdered soap container, and individual paper towels, shall be provided.
4. The building and fixtures shall be kept clean and sanitary at all times

GRADE C COMFORT STATION

Water Supply

1. All Grade C comfort stations shall have conveniently available a safe drinking water supply free from sanitary defects and conforming to the standards of the United States Public Health Service.
2. No common drinking cup or glass shall be permitted.

Toilets

1. Two sanitary pit, or other approved type, outdoor toilets shall be provided, separate for men and women.
2. These shall be constructed, maintained and operated in accordance with the principles outlined in bulletin No. 20, State Board of Health of Missouri.

For the present these three grades of comfort stations have been established in order that safe facilities can be provided that are consistent with the amount of traffic and local conditions. While grade A stations are being urged wherever possible and will be practically the only type along the more important routes, there will be for the present a large number of B and C type along less important highways.

The Division of Sanitary Engineering of the State Board of Health has made a field survey of all places along the National highways in Missouri that are interested in complying with these specifications and are adaptable by location for this purpose. The survey of the water supply upon which approval is based takes into consideration the location as regards possible sources of pollution; the construction of well or cistern, including type and condition of walls or casing, design and condition of pump, surface protection and other features which influence the safety of the water supply; and bacteriological examination of a sample. The requirements are explained and instructions left covering the improvements necessary. Samples are collected for bacterial analysis only from those water supplies which upon careful field survey prove properly protected.

After completion of the necessary improvements, as outlined at the time of the survey, application is made on a standard blank to the State Board of Health for reinspection. If upon reinspection the comfort station meets the State Board of Health requirements, the Highway Department is notified and a standard sign is placed upon the right of way, indicating the approval of the comfort station. In addition a certificate of approval is issued to the comfort station indicating that the conditions meet the State Board of Health specifications for an approved comfort station, and the grade of same. Several inspections will be made each year of the approved comfort stations, including periodic bacterial examination of the water supply. The possession of the highway sign and the annual renewal of the certificate of approval will be dependent upon the result of these inspections.

Standard signs will also be used at city limits to inform the tourist with regard to the safety of the city water supply where such supplies exist. Every city and town on a highway with a municipal water supply will wish to receive the approved water signs. The majority of these supplies are safe and those which need improvements will be given every opportunity and aid in bringing their supply up to the standard. The program also includes a survey of city tourist camps and recommendations for changes necessary to meet the specifications for an approved highway rest station.

The signs to be used to indicate approved comfort stations and safe water supplies are similar to the national highway signs in that they are standard for use on all national highways traversing the United States. Therefore, the autoist will soon become acquainted with these signs and will know the advantages offered regardless of the particular locality.

PROGRESS OF WORK

The increase in highway traffic has been an incentive to the establishment of business places catering to the needs of the automobilist. These establishments for the most part consist of filling stations, garages, tourist camps and stores where food can be obtained. These private concerns have shown exceptional interest in the program for highway comfort stations and a large number have already started or completed improvements to comply with the specifications of the State Board of Health for a sanitary comfort station.

During the past seven months one man's entire time was spent covering the 2750 miles of national highways supervising this program. During this period 591 inspections were made of 325 comfort stations. Reinspections have been made of 209 of these stations one or more times.

Of the water supplies for these comfort stations 231 come from privately owned wells or cisterns and 102 from municipal water systems. Of the privately owned water supplies 90 or 39 per cent have been improved to meet the specifications. Water supplies from municipal owned sources were satisfactory except in 4 instances. The total number of satisfactory water supplies available at comfort station is 188.

Sanitary toilet facilities are provided for by privies at 202 comfort stations, by city sewers at 55, by septic tanks at 62 and by chemical toilets at 21. A total of 81 comfort stations have improved toilet facilities to meet the specification, which in addition to those already satisfactory brings the total number of comfort stations with sanitary toilets to 198. Complete improvements, including safe water supply, sanitary toilets and necessary equipment, have been secured at 39 comfort stations or 12 per cent of the stations inspected. These places have received certificates and have been approved for the highway sign. Many comfort stations, as indicated above, have made decided improvements, but could not be approved because of failure to meet the requirements in a few details. The necessity for strict compliance with the specifications has been emphasized and this has doubtless resulted in fewer but more satisfactory comfort stations.

The present program for highway sanitation in Missouri is comparatively new. The work has received public approval, however, to a marked degree. By providing sanitary toilets and safe drinking water supplies along the highways, the dual purpose of highway sanitation, namely, the protection of permanent residents and the traveling public, will be to a large degree accomplished. This new phase of sanitary engineering does not offer an immediate method for evaluation. However, as a result of these sanitary improvements, the future holds prospects for an appreciable reduction in vacation typhoid and other filth-borne diseases which have recently shown considerable increase. In addition to better health protection of our highway population, considerable value of an educational nature will result from this work in the rural communities. Obviously a general program for sanitation of rural communities, although greatly needed, would require a considerable increase in personnel of the present state board of health. The establishment of safe water supplies and sanitary toilets at comfort stations will constitute a constant demonstration in sanitation to the surrounding community and unquestionably an influence for better conditions in general.

A highway system provided with well marked and located rest stations will not only afford proper sanitation and health protection for the rapidly growing population traveling our highways, but a convenience that will aid materially the comfort and pleasure of the autoist and one that the general public understands and appreciates.

SUMMARY

The increase of highway traffic in Missouri, resulting from the use of more automobiles and progress made toward completion of the hard surfaced road program, is rapidly creating a sanitary condition which demands attention for public health reasons. The large population, from widely scattered localities, traveling the highways during the day and sleeping in tourist camps at night, is dependent upon the drinking water and comfort station facilities afforded by the highways. Opportunities for the spread of infection are manifold unless proper supervision of water supplies and sanitation of environment of the highways is maintained. This is a highway problem and necessarily, therefore, statewide. It should for this reason come under control of the State Board of Health. In Missouri a program of co-operation between the State Board of Health and the State Highway Commission has been initiated whereby comfort stations are established under private or municipal ownership along the highways. These, if maintained according to State Board of Health specifications, receive a special highway marker placed and maintained by the State Highway Commission and a written certificate of approval from the State Board of Health. The many improvements secured as a result of one season's work indicates that this program has thus far been received favorably by the traveling public and owners of establishments who are interested in providing comfort stations.

The development of this program should offer a solution to the most important highway sanitation problems and greatly enhances the convenience and pleasure of highway travel.

CHLORINATION FOR ALGAE CONTROL

By Chester Cohen[1]

The control of taste and odor has been one of the chief difficulties experienced in supplying a palatable water in Texas during 1926. Some 117 towns are using surface water for domestic purposes, and in a majority of cases an impounding reservoir or lake is used for storage purposes. These surface reservoirs occupy on an average an area of perhaps seventy acres, with an average depth of not more than ten feet. A great proportion of our surface water contains a large amount of bicarbonate alkalinity. This characteristic, together with the long periods of sunlight and fairly high temperatures, creates extremely favorable conditions for algae multiplication. The density of plankton life in these reservoirs is relatively high, due to the limited volume of water coming in from water sheds of small area, and the depth of penetration of the sunlight through the relatively clear waters. This is productive of heavy growths of plankton and subsequent production of objectionable tastes and odors. The surface waters of the state support a large number of the typical plankton forms, among which oscillaria, spyrogyra and navicula are the forms most commonly occurring from the three main algae divisions. The general preparatory training of the ordinary plant operator in Texas does not include microscopical work and usually the first indication that he may have of a large increase in the plankton life is an increased color in the water or complaints of taste and odor from the consumers.

In such cases the usual copper sulphate remedy is applied, calculations being made from the standard dosage table as compiled by investigators some years ago. The treatment is applied either by dusting the crystal lightly over the water surface, by solution feed, or by dragging a sack of the chemical through the water at the end of a boat. Here, as in other states, this method has given satisfactory results where properly and sufficiently frequently applied. For large bodies of water the Texas State Board of Health has felt justified because of its experience, in continuing to recommend copper sulphate treatment.

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[1] Sanitary Engineer, State Board of Health, Austin, Texas.

ALGAE TROUBLES IN SMALL RESERVOIRS

There are a number of surface or combined surface and well supplies which do not use large impounding reservoirs. Such systems rely, for storage, upon a series of large concrete or earthen basins holding from one to ten million gallons of water. These basins are designed to provide temporary storage of one or more days' supply to serve in the event of a plant breakdown or necessity of machinery repair. A constant flow passes in and out of these tanks. Short circuits occur and the period of retention is subject to considerable variation. Some of these collection or storage basins, especially where well water constitutes the bulk of the supply, provide a retention period of only a few hours. Such well supplies, of which there are a large number in Texas, have a bicarbonate alkalinity content of 200 parts per million, or more. Being exposed to the sunlight and favorable temperature conditions, they often support a considerable algae growth. It has been difficult to keep the side walls of the storage tanks free of algae. The seeding of these tanks from the incoming water and from the air, together with the organisms that develop in the stagnant corners and dead areas, impregnates the remainder of the system and subsequent growths are especially noticeable in the sedimentation and coagulation basins where there is a high concentration of free carbon dioxide gas. Finally the whole plant including the filter beds may be affected. The advisability of covering these basins has often been discussed. The large surface area, the considerable expense, and the necessity of having the basin readily accessible for cleaning has resulted in this remedy being considered in most instances impractical. It has previously been the custom to drain and clear these tanks at such intervals as necessary—sometimes as often as every three or four days. The floors and walls are swabbed with a strong copper sulphate solution and then the basin is flushed and refilled with a fresh supply. The costs of the wasted water and the extra pumpage involved, of labor for this operation and of chemicals used, and the fact that the reservoirs are out of service over this considerable period of time make this method of control unsatisfactory. Furthermore, our attention has been directed to certain data and experiments by chemists and engineers which seem to indicate that previous ideas concerning the action of copper sulphate in water might be erroneous. Some of these data show that copper salts do not necessarily precipitate as hydroxide, but remain in solution and so are passed on to the consumer—a questionable practice if we are to regard copper as a cumulative poison. This fact, if true, becomes of especial importance because of the short storage period which these particular types of surface supplies receive. Because of the possibility of incomplete precipitation of the copper, and still further because of the uneconomical procedure involved in copper sulphate treatment of these small retention basins, the Texas State Board of Health undertook an investigation of the possibility of using some other medium as an efficient and economical algicide.

EXPERIMENTS AT MEXIA, TEXAS

The first observation and experimental work was begun at Mexia, Texas during the spring months of 1926. The water here consisted of a combined limestone spring and deep well supply. The spring supply is pumped directly from the spring collecting basin and the well supply from an open earthen collecting basin of 40,000 cubic feet in area at the wells. The two supplies mix in a large concrete settling basin of approximately six million gallons capacity located in the city. Seeding of algae undoubtedly took place in all three of these open basins. Unusually high densities of oscillaria and protococcus forms were generally found in the concrete service reservoir. Stagnant areas of this reservoir provided seeding beds for the algae and in several instances the water turned a decidedly green color within a few days, at the same time exhibiting a strong fishy and disagreeable odor. Inasmuch as the two most common methods of control, i.e., copper sulphate as an algicide, or covering of the reservoir, were impractical at this point, it was necessary to employ a different type of algicide or else attempt to inhibit algae development through the elimination of potential food supplies. Accordingly, laboratory experiments were conducted with these different waters and included both of the above methods. Table 1 indicates the results obtained.

From table 1 it seems reasonable to conclude that the lime treatment of this supply for the purpose of efficiently softening it would have resulted in a considerable reduction of the algae growth. This reduction in algae concentration was, of course, to be expected inasmuch as the the necessary food supply was removed, thus preventing the continuation of the life process of the organisms. Further experiments together with observation and data from other Texas plants substantiated the correctness of the above results. It must be borne in mind, however, that complete softening is not always practicable due to the particular layout of a plant not originally designed to serve as a softening plant. The construction of additional necessary treatment units at that time, with the necessity of changing the type of operation and of employing more skilled water plant

TABLE 1

Lime treatment

	SAMPLE TREATED FOR	SOURCE	RESULT
a	CO_2 removal	Well	Algae growth not inhibited
b	CO_2 removal	Spring	Algae growth not inhibited
c	CO_2 removal	Spring	Algae growth not inhibited
d	CO_2 removal	Mixed	Algae growth not inhibited
e	CO_2 removal	Mixed	Algae growth not inhibited
f	Partial softening	Well	Algae growth not inhibited
g	85 per cent softening	Well	Algae growth inhibited
h	85 per cent softening	Well	Algae growth inhibited
i	85 per cent softening	Well	Algae growth inhibited
j	85 per cent softening	Well	Algae growth inhibited
k	85 per cent softening	Spring	Algae growth inhibited
l	85 per cent softening	Spring	Algae growth inhibited
m	85 per cent softening	Well	Algae growth inhibited
n	85 per cent softening	Mixed	Algae growth inhibited

TABLE 2

Chlorine dosage

NUMBER OF SAMPLES	SOURCE	CHLORINE DOSAGE	EFFECT ON ALGAE
		p.p.m.	
3	Spring	0.25	Algae development partly inhibited
2	Well	0.25	Algae development not inhibited
3	Mixed	0.25	Algae development not inhibited
1	Well	0.5	Algae development not inhibited
2	Well	1.0	Algae development not inhibited
2	Spring	1.0	Algae development inhibited
4	Mixed	1.0	Algae development almost inhibited
1	Spring	1.5	Algae development inhibited
1	Well	2.0	Algae development inhibited
1	Spring	3.0	Algae development inhibited
2	Mixed	3.0	Algae development inhibited
1	Well	4.0	Algae development inhibited

operators was not considered advisable. At this particular place, lime softening, although economically advisable, would not have proved practicable as an immediate corrective measure.

TABLE 3

Dissipation of chlorine

CHLORINE DOSAGE	RESIDUAL CHLORINE AFTER			EFFECT OBSERVED 6 DAYS AFTER TREATMENT
	24 hours	48 hours	72 hours	
p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	
0.1	0.05	0.0	0.0	D and L
0.1	0.05	0.0	0.0	D and L
0.4	0.30	0.2	0.0	D
0.5	0.2	0.01	0.0	D
0.5	0.1	0.01	0.0	D and L
0.5	0.3	0.05	0.0	D
0.6	0.3	0.05	0.0	D
0.8	0.4	0.1	0.05	D

D = dead organisms; L = living organisms.

TABLE 4

Dissipation of chlorine

CHLORINE DOSAGE	RESIDUAL CHLORINE AFTER			EFFECT OBSERVED 6 DAYS AFTER TREATMENT
	1 day	2 days	3 days	
p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	
0.2	0.1	0.0	0.0	
0.3	0.1	0.0	0.0	
0.4	0.2	0.05	0.0	
0.4	0.2	0.05	0.0	
0.5	0.2	0.05	0.0	D
0.75	0.2	0.05	0.0	D
1.3	0.2	0.05	0.0	D
1.5	0.2	0.05	0.0	D
1.5	0.2	0.05	0.0	D
1.5	0.2	0.05	0.0	D
1.8	0.3	0.05	0.0	D
2.2	0.4	0.05	0.0	D

D = dead organisms.

CHLORINATION EXPERIMENTS

Experiments with the use of chlorine as an algicide were then begun. In this work it was realized that, if chlorine gas should prove efficient, a considerable saving in cost of installation and operation would result. The plant was already applying chlorine for the purpose of bacteria removal. The first experiments with chlorine were conducted in the laboratory in order to secure information as to the quantity of chlorine required to effect algae destruction. The effect secured in the preliminary tests is shown in table 2.

From the results of this experiment we felt inclined to believe that chlorine could be used to practical advantage in algae control. Further experiments undertaken in the laboratory are tabulated in tables 3 and 4.

As a result of these experiments chlorination of the water was begun at each of the sources already described, namely, the spring and the well reservoir. This dosage was applied at the rate of about one part per million. As long as it was continued it consistently succeeded in preventing a recurrence of the heavy algae growth. However, complete freedom from algae forms was not attained, probably due to constant reseeding from the spring supply and possibly also air contamination. A temporary breakdown of the chlorine machines with a consequent reduction of the dosage resulted in an unusually heavy regrowth of algae.

EXPERIMENTS AT LUFKIN, TEXAS

The degree of success obtained at Mexia determined the investigators to follow the same procedure at Lufkin, Texas some months later. Here the installation consisted of a series of four open round concrete tanks about 50 feet in diameter. The supply is obtained from a deep well, the water from which is high in iron content and bicarbonate alkalinity. After nozzle aeration and passage through a coke bed (fig. 1) the water passes through the settling tanks in series and is then pumped into the distribution system. Chlorine is applied at the pump suction line for bacterial control. These tanks hold about 200,000 gallons each. The total daily pumpage averages 500,000 gallons. This means that about one day's retention period is provided in these tanks for the purpose of settling out the suspended iron. The operation of this system is hampered during the summer months due to heavy growths of spirogyra developing in the tanks within a period of a few days. This growth would become so heavy and thick that it necessitated regular weekly emptying and cleaning of the tanks. The operation data for the plant indicated that the water wasted during the cleaning of the tanks cost $13.50 per month and the additional pumpage and labor involved cost $30.00 per month, This, together with the cost of the chemicals used, the wash water

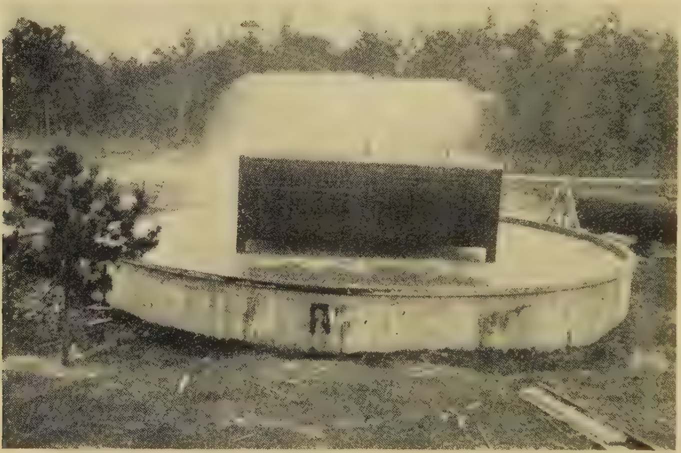

Fig. 1. Aerator and Coke Filter at Lufkin, Texas

Fig. 2. Typical Small Earthen Reservoir in Texas

for flushing the tanks and other incidentals, made a monthly item of $88.50 for algae control at this plant.

Based upon the favorable results in the Mexia experiment, the investigators decided to combine the chlorination for bacterial purposes and that for algae control into one treatment and to apply the chlorine at the inlet to tank 1, i.e., by prechlorination. The chlorine treatment was increased to 1.1 p.p.m., which represented a 50 per cent increase over the previous doses applied to the settled water for bacterial removal alone. The cost of this increased chlorine dosage amounts to $6.00 per month against the former figure of $88.50 per month for washing out the tanks and treatment with copper sulphate. This method of chlorine treatment has now been in operation at the Lufkin plant for a period of seven months or more and in that time it has not once been necessary to clean the tanks. The

TABLE 5

Data on treatment of water containing oscillaria and diatoms

(750 standard units per cubic centimeter)

SAMPLE	TREATMENT	DOSAGE	EFFECT OBSERVED (DAYS FOLLOWING CHLORINE APPLICATION)		
			3	5	8
a	Chlorine	0.05 p.p.m. residual	D	D	D and L
b	Chlorine	0.50 p.p.m. residual	D	D	D and L
c	Lime	CO_2 neutralized	D	D	D
d	Lime	Bicarbonate (neutralized)	D	D	D
e	None		L	D and L	D and L

D = dead organisms; L = living organisms.
Chlorine samples later became reseeded from the air.

TABLE 6

Data on treatment of water for algae control

SAMPLE	TREATMENT	DOSAGE P.P.M. RESIDUAL	EFFECT OBSERVED (5 DAYS AFTER CHLORINE APPLICATION)
a	None	0	L
b	Chlorine	Demand only	D and L
c	Chlorine	0.25	D
d	Chlorine	0.50	D
e	Chlorine	0.75	D
f	Chlorine	1.0	D
g	Chlorine	2.0	D
h	Chlorine	3.0	D
i	Chlorine	5.0	D

TABLE 7

Effect of chlorine on spirogyra

SAMPLE	TREATMENT	CHLORINE DOSAGE	EEFFCT OBSERVED (CONTACT PERIOD IN HOURS)							
			1		3		6		12	
			Residual chlorine	Algae	Residual chlorine	Algae	Residual chlorine	Algae	Residual chlorine	Algae
		p.p.m.	*p.p.m.*		*p.p.m.*		*p.p.m.*		*p.p.m,*	
a	None		0	L	0	L	0	L	0	L
b	Chlorine	0.2	0.05	L	0.04	L	0.01	L	0.01	D and L
c	Chlorine	0.5	0.1	L	0.07	L	0.05	L	0.03	Af and D
d	Chlorine	0.7	0.2	Af	0.1	Af	0.07	A and D	0.05	D
e	Chlorine	0.9	0.2	Af	0.2	Af	0.1	Af and D	0.07	D
f	Chlorine	1.0	0.2	Af	0.2	Af	0.15	D	0.08	D
g	Chlorine	1.2	0.2	Af	0.2	Af and D	0.2	D	0.1	D
h	Chlorine	1.5	0.2	Af	0.2	D	0.25	D	0.15	D
i	Chlorine	2.0	0.2	Af	0.2	D	0.3	D	0.2	D

D = dead organisms; L = live organisms: Af = affected organisms.

TABLE 8

Effect of chlorine on pure culture of oscillaria

SAMPLE	TREATMENT	CHLORINE DOSAGE	EFFECT OBSERVED (30-MINUTE CONTACT WITH CHLORINE)
		p.p.m.	
a	None		L
b	Chlorine	Satisfy chlorine demand	L
c	Chlorine	0.1 residual chlorine	L
d	Chlorine	0.2 residual chlorine	L
e	Chlorine	0.3 residual chlorine	L and D
f	Chlorine	0.4 residual chlorine	L and D
g	Chlorine	0.5 residual chlorine	D
h	Chlorine	0.6 residual chlorine	D

Note: After one-half hour, the excess chlorine was neutralized with sodium thiosulphate and a considerable period of time was then necessary before the organisms gave evidence of having been affected. The chlorine appeared to have exerted a feeble inhibitory effect rather than an immediate lethal effect. (See table 9.)

operator informs us that the sides and walls of the basins are always clean and free from algae. The treated effluent is as satisfactory from a bacteriological standpoint as previously, having a total count of less than 20 bacteria (37°C.) and with no indications of B. coli.

Since that time additional laboratory experiments have been carried on in order to determine the action occurring after the chlorine has disappeared, what regrowth of algae might be expected, the exact dosages necessary for various species of algae and the period of contact necessary to insure complete killing. Tables 5 to 12 inclusive give some information on these matters.

TABLE 9

SAMPLE	EFFECT OBSERVED (HOURS AFTER NEUTRALIZING CHLORINE TREATMENT IN TABLE 8)				
	0	6	24	48	72
a	L	L	L	L	L
b	L	L	L	L	L
c	L	L	L	L	L
d	L	L	L and D	L	L
e	L	L	L and D	L	L
f	L	L	L and D	L	L
g	L	L	D	L	L
h	L	L	D	D	D

Note: Evidently some spores or seed had remained alive in sample (G) and developed later.

TABLE 10

SAMPLE	TREATMENT	CHLORINE DOSAGE	EFFECT OBSERVED (TIME OF CONTACT WITH CHLORINE—20 HOURS*)	
			Residual chlorine after 20 hours	Algae
		p.p.m.	*p.p.m.*	
a	None		0.0	L
b	Chlorine	0.1	0.0	L and D
c	Chlorine	0.2	0.01	L and D
d	Chlorine	0.3	0.01	L and D
e	Chlorine	0.4	0.01	L and D
f	Chlorine	0.5	0.03	L and D
g	Chlorine	0.6	0.05	D

* These results were immediately noticeable without having to wait for after effects.

D = dead organisms; L = living organisms.

From tables 5 and 6 it is noted that after five days an algae redevelopment occurs, due to reseeding, to possible spores, or to resistant forms which were not affected by the chlorine treatment. In table 5 it is interesting to point out further that those samples which were chlorinated are the ones that show evidence of regrowth, whereas the samples in which lime treatment was used do not exhibit this regrowth. The regrowth in the chlorinated samples did not appear, however, until the eighth day following chlorination.

TABLE 11

CHLORINE DOSAGE	EFFECT OBSERVED (PERIOD OF CONTACT)					
	1 hour		6 hours		48 hours	
	Immediately	48 hours later	Immediately	48 hours later	Immediately	48 hours later
p.p.m.						
0.2	L	L	L	L		L
0.5	L	L	L	D and L		L
0.7	Af	Af	D	D and L		D
0.9	D	D	D	D		D
1.0	D	D	D	D		D
1.2	D	D	D	D		D
1.5	D	D	D	D		D
2.0	D	D	D	D		D
0.0*	L	L	L	L		L

* Control sample.

TABLE 12

Effect of chlorine on protococcus forms (copper sulphate resistant)

CHLORINE DOSAGE	EFFECT OBSERVED (PERIOD OF CONTACT)				
	14 hours		24 hours		48 hours
	Residual chlorine	Algae	Residual chlorine	Algae	Algae
p.p.m.	*p.p.m.*		*p.p.m.*		
0.0	0	L	0	L	L
0.5	0	L	0	D	D
1.0	0.1	D and L	0	D	D
1.5	0.5	D and L	0	D	D

Table 7 indicates much the same information as that collected at Lufkin, namely, that a dosage of over 1.0 p.p.m. is required to effect killing of the organisms within six hours, whereas a dosage of 1.5 p.p.m. is effective within three hours and even as slight a residual as 0.05 p.p.m. will have some effect after twelve hours.

The two tables 8 and 9 taken together seem to indicate that even small dosages of chlorine are effective after a period of time and seem to exhibit an effect that is not immediately observed.

Data in table 11 indicate the difference in the immediate and after result of chlorine treatment. Periods of contact with the chlorine of one, six, and forty-eight hours were allowed, after which the excess or residual chlorine was neutralized. Examinations of the samples were made immediately after neutralizing the residual chlorine, and another two days later.

Table 12 covers experiments with protococcus forms which appeared especially resistant to copper sulphate treatment. From this experiment they appear to be susceptible to chlorination.

From these data chlorine appears to be an especially valuable agent in water treatment plants for the purpose of algae control in those cases where copper sulphate is not practical or efficacious.

SUMMARY AND CONCLUSIONS

1. Since chlorine can be employed as a combined bactericide and algicide, the expense of installation and operation of additional chlorination units is not excessive.

2. The residual chlorine which is necessarily maintained to insure sterilization becomes effective toward inhibiting algae growth.

3. The simplicity and economy of chlorine application and the minimum of labor and experience involved recommend its use.

4. Since chlorine does not remain in the treated water no danger exists in cases of over-dosing.

5. From the field and laboratory data chlorine appears to possess merits that make it worthy of greater consideration in algae control work.

In closing, we wish to emphasize the fact that this work represents only the results of a comparatively short period of study. The collection of additional information and data on this subject is desirable.

THE PITOMETER SURVEY IN THE IMPROVEMENT AND MAINTENANCE OF A DISTRIBUTION SYSTEM[1]

By Meyer Serkes[2]

The pitometer, which in recent years has been discussed so extensively in water works manuals, needs no introduction to water works men.

In 1912 the Water Division of the City of St. Louis adopted the pitometer as a means of detecting, measuring and curtailing its waste of water. At this time the Pitometer Company contracted to make several leak surveys in districts covering a greater part of our down town section.

In brief this survey is carried on in the following manner:

The distribution system is divided into districts of suitable size, depending upon the available feed mains, the class of consumers, location of valves and the fire hazard to be created. One main is selected to supply the district under investigation and all other feeds into this section are closed. The pitometer is placed upon this main to record the amount of water entering this district per twenty-four hours. From this record the minimum night rate between the hours of 12:00 midnight and 3:00 a.m. are compared with the total twenty-four hours consumption. Districts where the minimum night rate obtained is 40 per cent or less, would be considered as good tight sections; but if it were to run 50 per cent and over, such a district would be further subdivided and the excessive night rate of flow accounted for. The larger commercial meters would be read during the night period and accounted for in the study of the night flow.

In this further subdivision, sections are readily detected which are free from leakage. Sections which show small flows during the period of minimum night flow, indicate fixture leakage and would require a house to house inspection. Sections where large flows are recorded would indicate large water main leaks, service pipe leaks, or a larger number of fixture leaks.

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[1] Presented before the Iowa Section meeting, November 4, 1926.

[2] Assistant Engineer, Distribution Division, Water Department, St. Louis, Mo.

All these conditions are thoroughly investigated by the pitometer engineer until all leaks have been located and repaired, after which the district is again remeasured to note the improvement made.

During the progress of such a leak survey much valuable information as to the condition and location of valves, hydrants, meters and other appurtenances of a system is collected, and the errors readily detected and corrected.

The results of such a survey in 1912 showed conclusively the advisability of continuing such work, and the department purchased several pitometers and has since maintained its own Pitometer Department which has been carrying on this routine leak detection work on a small scale to very good advantage.

During the past year a second class residential section was surveyed, in which the following leaks were detected: 371 faucet and toilet leaks, 3 service pipe, 3 fire hydrants and 10 street valves. These leaks constituted a wastage of 327,000 gallons per day or 119.6 million gallons per year. During the house to house inspections in this district, additional revenue was added, in that 381 automobiles and 161 washing machines, which are taxed on a flat rate basis, were placed upon the books.

The section investigated, comprising a population of 20,000, showed a consumption of 96 gallons per capita before, and 88 gallons after, the leaks were taken up.

These figures, which are far below the general average consumption of 145 gallons per day for the entire city, prove the section to be a good one and seem to indicate that the consumption in the industrial districts must be responsible for the increased per capita consumption.

In the early routine pitometer leak work it soon became apparent to us that a broader and more comprehensive use of the pitometer could be made in a study of the exact flow conditions existing during maximum and minimum periods of the day in all the main feeders of the distribution system.

Since this time the department has continued using the pitometer in making distribution feeder surveys yearly, whereby some mains were found to be doing no work whatsoever, and others as doing more than their share, with velocities higher than desirable causing excessive friction losses in the line.

These data obtained yearly are used to very good advantage in new distribution design, and in the modification of the existing system, so as to equalize the work by the various overtaxed feeders, thereby enabling better pressures to be maintained at critical points in the system.

In one instance, a few years ago, it was observed, from pitometer flow readings, that none of the low pressure main feeders on and east of Grand Avenue, which supply the Compton Hill Reservoir, were taxed to capacity; that about 50 per cent of their total flow was supplied directly to the reservoir during the night period, between 6:00 p.m. and 6:00 a.m. The central feeder in this district, a 36-inch main on Twentieth Street, was observed to deliver practically no water from Chouteau Avenue southward, either during the day or night.

When the problem of providing a new outlet for a high pressure pump from Bissell's Point to a section in South St. Louis, which was giving us trouble during periods of high consumption, came up for consideration, it was decided to take advantage of the condition found to exist in this Twentieth Street 36-inch main and turn it into a high pressure feeder.

By some minor changes and disconnections from this Twentieth Street main, it was directly connected to the high pressure pump and made to carry water at the rate of 15 million gallons per twenty-four hours, into this critical section of South St. Louis, thereby avoiding the laying of a new 36-inch main as was proposed previously at a saving of $140,000 and increasing pressures about 14 pounds at this critical point.

The St. Louis distribution system, you may be interested to know, consists of two pressure systems, a high and a low, each being separated in the system merely by the closing of certain valves. The high pressure system renders service to the higher elevations in the west and southern parts of town, while the low pressure takes care of the lower elevations in the east or downtown sections and the extreme south. The high pressure starts with 120 pounds at Baden Station and the low pressure with 80 pounds at Bissell's Point.

In another case it was observed that a 30-inch low pressure feeder in Forest Park Boulevard from Grand Avenue to Sarah Street was carrying an almost insignificant amount of water. By a few additions and cross connections to this main it was taken out of low service and turned into a high pressure feeder so as to augment a 36-inch high pressure feeder across Grand Avenue which was congested during periods of large consumption between Bissell's Point Station and a point south of Olive Street.

During the past spring when an important 36-inch cross town feeder had to be shut down in a certain section to make repairs, it was thought that an existing cross connection to this feeder, just north of the point where the repairs were to be made, would divert most of the water eastward, and into another cross town feeder which was not taxed to capacity.

Upon checking up with the pitometer the estimated flow that this cross connection was to carry, it was discovered that the main carried no water, whatever and, immediately upon checking the valves on this line, we found a valve closed which was supposed to be open.

Last year a pitometer flow survey was made upon all the high pressure feeders of 20-inch and over, in which valuable data were obtained, whereby recommendations were made for changes now in progress to the present system. When completed and inter-connected with the new Missouri River source, these will give a direct supply to those sections in South and West St. Louis which are urgently in need of relief.

The use of the pitometer, therefore, as you see, is an important factor in the study of the correct functioning of a distribution system.

A number of years ago an extensive pipe cleaning program was undertaken to reduce the friction losses and to restore the carrying capacities of some of our oldest mains, which have been in service previous to the installation of our rapid sand filtration process.

In this work the pitometer was used extensively in determining the pipe coefficients, friction losses and carrying capacities of the various mains before and after cleaning.

The contractor guaranteed to restore the carrying capacities of mains cleaned to within 5 per cent of that of new pipe, using Weston's table of flows as a basis. Tests made upon some of the mains, before cleaning was started, showed carrying capacities from 40 to 60 per cent of new pipe and tests run immediately after the cleaning showed gratifying results of 95 per cent of new pipe.

These same mains were retested year after year until today some of them have dropped as low as 70 per cent, although most of the larger mains have held up to a much higher percentage.

The intention of the Cleaning Company at that time was to restore the pipe to its original diameter by getting out all the hard lime incrustation and mud, regardless of the condition in which the interior of the pipe was left. Because most of this lime scale was hard and adhered to the pipe very tightly, the contractor constructed what was called "saw tooth blades," which were very sharp and stiff, so as to make sure that they would remove everything and they certainly succeeded. They removed not only the lime incrustation, but also most of the tar coating which adhered to the bottom of the lime scale. In doing this the bare metal was exposed to the water and an iron incrustation immediately formed causing very rapid depreciation.

I understand today, however, that, from the experience gained here and elsewhere, this company is much better equipped to clean pipes, as they now make a complete study of the character of the water supply and plan the kind of a machine and the type of blade to be used to meet the local condition.

In many cases where it is expensive and difficult to take a large meter out of service for testing in the shop, the pitometer is resorted to in making a test in place with extreme accuracy.

A few years ago, in making such a test, a 6-inch meter was found to under-register about 15 per cent. This error was caused by an inexperienced meter man who made a change in dial gears in the field after making a small flow test. Since this meter supplied a very large consumer of water, the amount of unregistered water was estimated and a bill for several thousand dollars was presented and collected without much difficulty when the details of the incident were explained.

Again during the war period, the Government, which purchased water from us for its reservation through two 6-inch meters in parallel, disputed the correct registration of these meters, by a check at their Venturi meter in their pump station.

A test with the aid of the pitometer proved that our meters were within the limits of accuracy required and that the error was in the indicating device of the Venturi meter.

Such tests as these, where disputes occur and which are made in direct observation of a consumer, leave no doubt as to the merits of the case.

The problem of curtailing the waste of water, which invariably occurs in all unmetered cities and towns, is receiving more attention from engineers and water works officials today than ever before, owing to the fact that additional plant equipment and new sources of supply are becoming very costly.

The records of consumption in many cities clearly indicate that the amount of water wasted daily often far exceeds the quantity really necessary to meet ordinary demands. This waste results largely from the fact that most consumers fail to appreciate the value of an unchecked, abundant, pure water supply.

This excessive use of water not only reduces the pressure, which is felt immediately at the critical points of a system, but also increases the cost of pumping and taxes a plant to its utmost capacity. A breakdown at such a period would create a hazard.

During the past dry summer, when sprinkling was the general order of the day, our plant was taxed to its capacity of 160 million gallons daily and it became almost impossible to maintain pressures at some of the critical high points. As soon as the excessive sprinkling was discontinued, however, the plant output dropped back to its normal capacity of 130 million gallons daily and the average pressure increased from 5 to 15 pounds at critical points.

A legitimate use of the garden hose would not cause such an excessive waste. The unmetered or flat rate consumer, who allows his hose to run continuously all day long and has no idea of the real value of a good water supply, is one of the prime causes of excessive waste.

This same condition exists during the near zero weather in winter when faucets are allowed to run during the night, to prevent freezing of service pipes.

Since St. Louis is only 7.6 per cent metered, you can observe for yourself why our plant is called upon at various times of the year to deliver its rated capacity.

The excessive waste in St. Louis may be attributed to the following causes:

1. Leakage from defective plumbing and fixtures.
2. Excessive sprinkling and the promiscuous opening of taps.
3. The extensive use of free water in city institutions and parks and needless industrial waste.
4. Leakage from the underground system of pipes.

Leakage from defective plumbing and fixtures may best be controlled by systematic house to house inspections, regularly maintained by a permanent staff of intelligent inspectors, with the aid of the aquaphone, by good plumbing ordinances, or by the universal installation of meters.

Excessive sprinkling can best be curtailed by the enactment of laws restricting the use of the hose to certain periods of the day.

Extensive use in city institutions and parks can best be restrained by a closer coöperation between department heads and the water division. In one city institution alone a million gallons per day is used of which 30 to 40 per cent is purely waste.

At one fountain in a certain park, ½ million gallons are wasted daily. Such waste as this in parks and industrial plants could readily be conserved by the installation of a recirculating pumping system at a small initial cost.

The detection and the conservation of leakage in the underground system require the services of experts trained in this line, who can make an extensive pitometer survey.

The four means for reduction of excessive waste, which I have mentioned, have their particular merits. All remedies except the installation of meters are of a temporary value only and must be constantly repeated, and above all must be supported by strong laws and good plumbing ordinances to be effective.

There are many good reasons for the use of water meters. One of the most important is that selling water by measurement is the only logical and business-like way. This method is now used by all private utility corporations and should be likewise used by all municipal utility departments. It is the only method that does not result in gross inequalities and discriminations against some of the consumers in favor of others. Another reason is that the installation of water meters is the only practical method yet devised for restricting excessive waste.

The use of meters is now becoming much more general and in most cities today the large consumers, at least, are now metered. Here in St. Louis where we are 7.6 per cent metered, any connection other than one ¾-inch tap, which is now installed, requires a meter. Our present consumption per capita is 145 gallons. Under a totally metered system it woud probably be 100 gallons per capita.

I would not hesitate to estimate that the loss or waste of water due to small unmetered consumers averages 50 to 60 per cent of the total amount of leakage. The general use of meters should be the watch-word of the day in a modern water works system.

Usually there is a great deal of opposition raised to the introduction of meters, but in most cases it has been found that after they had been installed the good results which were immediately obtained caused them to be greatly favored by a community.

The general installation of meters in the following cities of Detroit, Milwaukee, Cleveland, Rochester, Baltimore, Los Angeles, and Atlanta, Ga., has in recent years greatly reduced the per capita consumption in these towns, thereby enabling a tremendous saving to be made in the cost of pumping, extension to the distribution system and in the chemical treatment of the water.

METER MAINTENANCE METHODS[1]

By J. H. Fagg[2]

For the purpose of this report a survey was made by means of a questionnaire returned by twenty-eight water companies in California, whose services were metered 80 per cent or over, and involving a total of approximately 640,000 services.

Of these twenty-eight, thirteen plants were municipally operated, and fifteen operated by private companies.

The questionnaire produced the following information:

1. Fifteen companies check all new meters for accuracy upon receipt.
2. Twenty companies use the round reading dials, and the cubic foot, with one exception, is the unit of measurement.
3. Only five are continuing the use of compound meters.
4. Fifteen of the twenty-eight are using batteries of small meters on the larger services.
5. But three of the companies test their meters periodically: one on a two-year schedule, one on a three-year schedule and one every four or five years. Also 2 remove their meters for test and overhauling after one complete revolution of the dial.
6. Practically all of the companies use the concrete meter box and set meters just inside of curb line where mains are carried in the street.
7. Eleven of those reporting are employing check valves to prevent hot water damage and bill consumers the cost of repairing the damage caused by hot water.

In analyzing the return on the questionnaire it appears that most of the companies realize the importance of testing new meters when received, and from the tone of some of the statements it is believed that it will soon be general practice to test all meters periodically.

The round reading registers are giving the best satisfaction, as they will operate over longer periods than will the straight reader.

The use of compound meters is being discontinued rapidly by nearly all of the companies and the use of batteries of small meters on large services is becoming popular with most water works men.

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[1] Presented before the California Section meeting, October 28, 1926.

[2] District Manager, Pacific Gas and Electric Company, San Joaquin Division, Stockton, Calif.

A very small percentage of those reporting are making a practice of testing meters in the field, and they have equipped their shops with standard test tables of standard manufacture and other necessary facilities for proper handling of meter repairs.

SOLVING THE SEAGULL PROBLEM IN SAN FRANCISCO

By George W. Pracy[1]

The city of San Francisco is located on a peninsula with San Francisco Bay on the east and north, the Bay gradually narrowing to form Golden Gate Straits with the Pacific Ocean on the west. The city has always been more or less infested with seagulls along the water front, though up to the past few years they have not come inland. These birds are great scavengers and it is unlawful to kill them.

The Spring Valley reservoirs, located in various parts of the city, date back to the early history of the city and were all uncovered. About ten years ago the seagulls started coming into one of our small reservoirs not far from the water front. We tried to chase them out without any success. They became so bothersome that we finally covered the reservoir. The birds then spread to three other reservoirs farther in town. These reservoirs are larger and owing to the existing conditions are practically impossible to cover. We tried to drive the birds away by shooting and finally purchased an automatic exploder which was only fairly successful.

About two years ago, one of our fellows visited the city of Victoria in British Columbia and came back with the report that they had had trouble with seagulls and had effected a cure by stringing wires across the reservoirs in about fifty-foot squares. We immediately tried this on one of our reservoirs measuring about two hundred feet square, stringing the wires forty feet apart in both directions and found it was entirely successful in keeping the seagulls away.

We next strung similar sets of wires over a larger reservoir, being circular in form and about four hundred feet in diameter. This also being successful, we proceeded to string wires over our largest reservoir which is irregularly shaped, but about one thousand feet long by six hundred feet wide. In the first two reservoirs, we used the ordinary No. 9 galvanized iron wire, commonly known as telephone wire. These were fastened to 2 inch pipe driven into the ground. On the large reservoir, we felt that wires of this size would not stand the strain necessary to keep them taut over so large a span, so we first installed a system of larger cables, $\frac{1}{4}$ and $\frac{1}{2}$ inch in diameter, using these to support the small wires. Two pipe supports resting on the bottom of the reservoir and spaced about $\frac{1}{3}$ of the way across were used to shorten the span.

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[1] Superintendent, City Distribution Department, Spring Valley Water Company, San Francisco, Cal.

A system would have to be worked out in detail for each size and shape of reservoir, but in our case it was comparatively simple and worked perfectly. The wires are pulled taut, the net work of wires being about one foot above the high water mark in the low part of the span.

The small reservoirs cost us about $50 for the complete job; the large reservoir cost about $400. The results have been entirely satisfactory. We get an occasional seagull, but they appear rarely and they do not stay.

NOTES ON PUMPING AND WATER WORKS OPERATION[1]

By McKean Maffitt[2]

In compressing air it is a known fact that it gets hot due to the rearrangement of the molecules as they are packed closely together. You absorb heat into the air and it gets so hot that every air compressor of high capacity has some good method of cooling. If it has not some method of cooling, it will burn up.

An Ingersoll-Rand, two straight line air compressor, has a low pressure cylinder that pumps air through a cooler that is built very much on the type of a water works condenser. The air then goes from that cooler to a high pressure cylinder and is recompressed and reheated. This is a typical illustration. An air pipe leads to a large receiver where you store the air for use so that you will not have pulsations in your pipe lines leading to your wells. As this air goes from the compressor to the receiver it carries a quantity of oil—a high volatile oil having a high flash point. That is, it will not ignite except under very high temperature. This high flash point oil is used for the purpose of resisting heat. Where you have taken air at atmospheric pressure and increased it to 105 pounds gauge pressure you have seven times the oxygen in the same bulk of space as under the atmospheric pressure. For each particle of oil in that receiver there is seven times the oxygen that there would be in the atmosphere. If it gets too hot the air receiver is liable to explode and the result will be equivalent to a boiler explosion. It would not have the result that a boiler explosion would have, because a boiler contains a large quantity of water which immediately flashes into steam when the pressure is reduced. But most receivers will have a large quantity of oil that is very hot and which will almost instantaneously flash when the pressure is reduced and original combustion stops. That is one danger to which every air receiver is subject and one that should be carefully watched to see that there is not an accumulation of oil in the receiver.

As your pipe line comes from the receiver and goes to the well, it is absolutely necessary that every joint be tight because a leak of a cubic foot of air from a joint in a pipe line—going back through the air compressor and figuring the efficiency of the air compressor—will require the compression of two feet. If an air compressor is operating at 50 per cent efficiency—and I imagine that most of them are operating at less than that—that same 2 feet of air going back to the pipe lines, which might be operating at an efficiency of 90 per cent will still further be increased until the boiler is reached. If the boiler is operating at 60 per cent efficiency you still have no increase. You put under the boiler enough coal to compress 3, 4, or 5 cubic feet of air and you take out of the air compressor perhaps 1 cubic foot of air. The further you get away from your boiler, the more benefit you get from stopping any kind of leak or increasing any kind of efficiency.

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[1] Presented before the North Carolina Section meeting, August 23, 1926.

[2] Superintendent, Water Works, Wilmington, N. C.

When your piping goes into your well and goes down, if you have a very high lift so that you must have exceptional submergence, you must generate enough pressure in the air receiver to blow off or take the head of water. For instance, if the static head in the well is at the surface, the draft head is 100 feet below the surface. The submergence should be figured on the draft, and not on the static head, because the draft head should be so arranged that the submergence will be about 65 per cent of the discharge.

If you add to that 65 per cent discharge, one hundred feet of static head in that well, the air pressure must be raised sufficiently above the working pressure to throw off that 100 feet. In that case there should be an auxiliary line run down into the well point at the draft head, the auxiliary line to blow off the 100 foot static head. Then immediately, or at the same time, open your working head and allow the air to go down to the point of discharge as determined by theory and practice. That will give you the best operation for your draft head. Cut off your auxiliary head then and allow the working head to carry on.

Most of the text books I have found on compressed air pumping from deep wells claim that water and air come out of the well in solution. I imagine the reason they make that claim is because it is easier for draughtsmen to show a slug of water and a slug of air coming out of a pipe than it is for them to show the air and water mixed.

During my years of experience in operating wells I have never found that a well discharged a slug of water and a slug of air.

The claim is made that the air acts like a piston and pushes the water out of the well, but the air does not act like a piston and push the water out of the well. The air is supposed to mingle with the water, to be thoroughly diffused throughout the water, thereby lessening the specific gravity of the column of water to such an extent that the pressure of ground water can force more water into the pipe.

As this little column of air and water is created in the pipe line, it necessarily rises to a point where it overflows at the surface. That is what brings the water out of the well.

In a great many installations, the pipe line is put down into the well and the nozzle shoots the air into the well in a stream or jet effect, jetting the water out and losing efficiency. If the pipe line is put down into the well, capped on the end, and filled full of small holes $\frac{1}{16}$ or $\frac{1}{32}$ inch—if it is a copper pipe a little bit larger hole is desirable than with the galvanized or wrought iron pipe—this air will come out into the water in a series of very fine streams which will cause more or less of an emulsion of air and water, the specific gravity of which should be 50 per cent the specific gravity of water. Then your column of water 100 feet high will weigh twice as much as your column of water and air, thereby obtaining a 50-foot lift.

"KINKS" IN OPERATION

In nearly every case where a contractor comes to town to pave streets various troubles result. Among others, corporation cocks may be broken off at the main by the plow or the skimmer shovel. In cases of this kind I use a long steel tool squared and tapered at each end, one end to enter the inlet end of a $\frac{3}{4}$-inch corporation cock and the other to enter the end of a 1-inch corporation cock. I insert the proper end of the tool into the brass ferrule left in the main and drive it home rather snugly. A pipe wrench will enable you to back the ferrule out of the main. Now take a closed corporation cock, insert the outlet end in the coupling of the proper size galvanized pipe and you can screw the cock into the main against the pressure. In case the main is so shallow that the force of the water coming out of it will jet all of the water out of the hole you can use two heavy boards laid down across the hole. Cut a V notch in each board, bring these notches together just over the hole in the main and then work down through these notches to the main. It requires a little nerve and a good grip to get the cock centered in the hole, but it can be done. I have found this was much better than cutting off the main, especially where it was a large main or one that supplied a manufacturing district. Then it is easier and cheaper. After you have inserted the cock in the main you can dig down to the cock and remove the pipe and then tighten the cock with a pipe wrench.

Some years ago we had a regular siege of blown out plugs. In some few months we had 5 16-inch plugs blown out. In every case it meant shutting down the plant until we could cut off the water. As our valves were not in good order at that time there was one case where we could not shut off the water tightly enough to work in the hole. All the trench pumps we had would not pump the water lower than half of the way down the bell. Do what we would, we could not get the hole dry enough to work in. I got a common screw jack and some heavy gum packing. I cut a gasket 1 inch wide, the diameter of the plug, tied this gasket to the face of the plug with cotton string and then inserted the plug in the bell, using the jack to force it to a seat against the gasket. This held the water tightly enough for me to yarn and pour the joint. The hole was practically dry after I had jacked the plug up against the shoulder in the bell. I have used this trick several times and each time it works more easily than it did the first time.

Some years ago I had a leak reported on a 12-inch main. When we opened it up we found that the spigot end of the pipe was cracked. The crack ran about 18 inches out of the bell. Rather than cut this section I used two clamps made of $\frac{3}{4}$-inch by 2-inch flat iron. These clamps were made in two sections, one-half circle in each section, with 3-inch lugs on the ends and 1-inch hole bored in each lug. The whole clamp is made so that it is a snug fit with about two inches clearance between the lugs when it is placed around the main. Use long threaded bolts through the holes in the lugs, first drawing tight the clamp further away from the bell, then tighten the next clamp. As you start to tighten the clamps, if you will take two light round pien hammers and lightly tap the pipe just on each side of the crack, you stand a better chance of getting a good tight joint, as the vibrations of the hammer blows cause the ragged edges of the iron to seat together more evenly.

In case the crack happens to be in the body of the pipe and not at the end, you can do the same thing. It is better, however, to start the two end clamps first, working gradually towards the center, that is, if it requires more than two clamps. The clamps should be spaced about 8 to 12 inches apart, depending upon how bad the crack is. If the crack is ragged and uneven there is no chance of making a fit. If the crack happens to have been caused by a blow from a pick and the pick stuck through the main, work the crack up to the hole caused by the point of the pick and then put a heavy lead gasket over the hole and a clamp over the lead gasket and draw the clamp up tight. Of course, you will get wet and all these cracks will happen in the winter time and at night, but then it is easier than to cut out a section and it costs about $\frac{1}{5}$ as much.

If any of you run a steam plant and have a number of small leaks in your steam lines that are too small to shut down to repair, or are such that one of these patent clamps will not take care of it, try this. Right at the boiler, in the horizontal pipe line, tap a small hole in the steam line. Insert a regular drip lubricator. Fill the lubricator with a mixture of cylinder oil and fine flake graphite. Make the mixture so that it will barely feed. Open the lubricator and let the mixture feed slowly into the line all the time. Attend this lubricator as regularly as you attend the lubricator on the main pump. In a few days you will fail to see any of those small steam leaks. The flake graphite will be carried into the crevices by the escaping steam and will effectually plug them up. If the graphite goes on over to the pump it will act as a better lubricator than the cylinder oil will.

In case you were tapping the main and should insert a corporation cock that was open you could not get the machine off the pipe without getting wet. I have done that very thing and got a good ducking from it. The next time this happened—and it will happen some times—I simply stripped the machine off the boring bar and then cut off the water at the cock and removed the bar. If you are very careful, remove the collar from the top of the boring bar of the tapping machine, take the upper part of the machine off over the boring bar, then remove the lower part of the machine the same way. It will leave the cock in the main and the boring bar in the cock.

In patching paved streets where there is a dense traffic and it would be inconvenient to leave the hole blocked off for some time while the concrete set up, I tried the following method: tamp the hole until it is as solid as you can make it. Make a mixture of concrete the same as usual only not so wet. Make it the consistency of stiff putty. Put this in the hole and tamp it hard. I mean hard, not just light taps. Tamp it until it is almost impossible to make an impression on it with the tamping iron. Put your top surface down on this tamped concrete. Bricks, sheet asphalt, Hastings asphalt blocks, Kentucky Rock asphalt or any other kind of surfacing. Cover the finished surface with about one inch of loose sand and open it to traffic. Nothing short of a ten ton load will affect it. There are about fifty such places here in Wilmington. It worked out so well that even on those streets where there is very little traffic we do the same thing. We never block off a paved street for the regulation ten days. Only just so long as it takes us to put in the material.

If any of you have charge of a sewer system this might be of interest to you. We had to run a sewer line to a section that had about twenty houses in it. To get to this section the line came to the surface of the ground. It was simply a case of leaving out this section or putting in an invert. So I tried the invert. I ran the line at the regular grade until it was within 6 inches of the surface. Then I built a man hole. The inlet lines to the man hole were put 24 inches below the outlet line. Thus the sewage had to rise 24 inches in the man hole before it would run out. The laterals on the low line were run out to the property line before any houses were connected up. At the ends of the two low lines there were installed flush tanks so that we could get a large flush of water once in a while. In the man hole at the break in the grade we installed a 1-inch water connection in such manner that we can turn the water on and break up the accumulation of sewage that collects here. About once every two weeks in inspecting sewers we go to this man hole and break up the scum and wash it down the sewer. This line has been in operation about two years and has not given any trouble. We deemed it best to have this lie this way than to have this section of the city using separate septic tanks that were always giving trouble.

We installed a line of Universal some time ago and the foreman in charge was a little skittish about the joints and had them pulled up hard and tight. About three years after installation trouble began to develop in every cold spell. We found that in taking out a broken section we were lucky if we got by without breaking at least five spigot ends. Thus there were always 25 feet of pipe that were wasted. That being too expensive, I had these flanged sleeves made and in case we have a Universal joint that leaks we put this around the joint, bolt it tight onto a lead gasket, yarn and pour the same as we would any other joint and that is the end of our trouble. About a week ago we had a 6-inch B. & S. line slump off the side of a hill and pulled a spigot so far out of the bell that you could stick a pencil into the joint. As it was impractical to straighten the line just at that time, we tried one of these joint sleeves and it worked so well that for the time being we have left the line as it was.

If any of you have any wrought iron lines that are pitted so bad that they develop leaks all over at once and it is not convenient to cut them out or relay them and they are so rotten that it is practically impossible to thread the pipe I know what you are up against. One of these small holes will make a bad place in the pavement, although it will not waste 100 gallons of water a day. It has to be repaired and it means taking out the whole line or at least one whole section so that you will not have to thread the pipe. If you will take a piece of soft white pine, taper it down to about the size of the hole in the pipe. Stick it in the hole and drive it in slightly. Draw it out and by examining the end that was in the hole you can get the exact shape of the hole. Now cut the stick so that it will have a slight taper and will be shaped almost like the hole in the pipe. Stick it in the hole and drive up rather tight. Be careful that you do not crush the stick, just tap it lightly until you have the leak stopped. Then carefully cut the stick off about $\frac{1}{2}$ inch from the pipe and go home and to bed. That stick will stay there as long as the main does. There is one line of pipe in South Carolina that looks like a porcupine, if it is still in the ground. I put about 50 sticks in it and when I left there the man in charge was putting in sticks.

Some months ago we had a considerable wash-out at a bridge. A 12-inch main joint blew out and before we could shut the water off it had washed out a bridge abutment. This abutment was 30 feet long, 24 feet high and 7 feet thick at the base. We decided to under-pin it rather than tear it down and rebuilt it. We jacked one end of the bridge off the abutment and proceeded to underpin. It was a ticklish job. The sub-grade was of loose sand. If we got below the blocking we had put under the abutment we were in for the loss of the whole thing and maybe the bridge too. As we poured the concrete under this abutment I found that it was practically impossible to pack it hard up against the brick. The more we tamped it the looser it got. It looked as if there was no chance, but to let the brick work settle about $\frac{1}{2}$ inch more as it came down onto the concrete. We did not want this to happen as the abutment was about one inch low already. I built my forms up in front of the cavity and poured them as full of concrete as I could. Still the concrete was not making a good joint with the overhead brick work. Then I took two pieces of 2-by 8-inch lumber dressed all around and sharpened at the ends. I cut holes in the forms that would let these pieces of lumber go through and then I drove these pieces into the mass of concrete just as close up to the brick work as I could get them. As they were driven into the mass of concrete they displaced just so much concrete and as there was no where for it to go but up, up it went and filled in that small cavity. After the concrete had set I pulled the forms and examined the joint between the concrete and the brick work and found that the brick work had almost as good a bearing on the concrete as if it had been put on the concrete instead of the concrete having been put under the brick work.

DISSOLVED OXYGEN CHANGES DURING FILTRATION[1]

By W. U. Gallaher[2]

In connection with experiments conducted at the Highland Park water filter plant to locate the cause of air-binding in filters, the dissolved oxygen was run on a sample of the water entering the filter bed and also on a sample taken from the effluent pipe of the same filter. An interesting fact was discovered. There was a decrease in dissolved oxygen, even though the filter on being washed did not show any entrapped air. This decrease was also evident when the water was not supersaturated with oxygen. It was decided to run a series of tests at intervals during the year when the water was at different temperatures and discover if the temperature had any effect on the decrease in dissolved oxygen during filtration.

There are few references in the literature dealing with changes in the dissolved gases of waters that are subjected to sand filtration. This is probably due to the fact that the changes are small, have no apparent practical importance, and vary (as in the case of most water problems) with the quality and treatment of the water. This means that numerous accurate determinations must be made before fair conclusions can be reached.

In Germany, Noll (1) made a very extensive and accurate study of dissolved oxygen changes on filtration and found that the change in dissolved oxygen in passing through sand filters was greater than the changes in the oxygen consumed. He states the oxygen may have been used up as follows: (*a*) by the bacteria, (*b*) by chemical reactions within the filters, or (*c*) by escaping from the filters. However, he attached little importance to the last possibility.

The raw water source at the Highland Park plant is the Lake St. Claire and is therefore a typical Great Lakes water. Its quality is practically the same the year round and it is an ideal water on which to make the determinations reported in this paper. It is pumped 11 miles before filtration against a 43-foot head, the pressure at the discharge of the pumps varying from 45 to 105 pounds per square inch. Hatfield (2) has previously reported how air-binding was traced to defective water seals on the lake pumps.

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[1] Presented before the Central States Section meeting, September 21, 1926.

[2] Superintendent of Filtration, Water Department, Highland Park, Michigan.

The mixing of air with water and immediately subjecting them to pressures greater than atmospheric causes the gas to go into solution in higher concentrations than when the water was in equilibrium with the atmosphere. Even after the water is exposed to atmospheric conditions in the coagulation basin the return to equilibrium is slow. On passing through the filters the return to equilibrium is hastened, air is released and accumulates in the voids of the sand and gravel. Baylis (3) states that the starting of release of air in filter beds is due entirely to bubbles being carried into the bed or to air left in the bed after washing.

It has not been proven that temperature has any relation to air-binding. Caird (4) reported that the release of air in filters occurred during cold weather when the water was at a temperature below 50°F. It is more generally conceded, however, that air-binding depends to a great extent on the handling of the water prior to treatment.

The procedure for the tests made was as follows: Samples were taken in triplicate of water on top of the filter and the temperature recorded. Immediately afterward three samples were taken from the effluent pipe of the same filter and the temperature recorded. All samples were taken in 250 cc. glass stoppered bottles and the dissolved oxygen determined according to the procedure given in the A. P. H. A. "Standard Methods for the Examination of Water and Sewage." Samples collected at low temperatures were placed in the ice box until final acidification to prevent any loss of oxygen.

Table 1 is a complete list of the determinations made. The figures given are the average of the three samples taken. Column T–E represents the diminution of dissolved oxygen on passing through the filter expressed in per cent saturation and column OT–OE gives the decrease in dissolved oxygen expressed in parts per million. Samples marked *a* and *b* are from the filter during the same run, sample *a* being taken at the start and sample *b* near the end. No change in concentration of carbon dioxide was detected. The dissolved oxygen of the raw water was run at first, but on account of several hours detention in the coagulation basin there was some variation between the raw and influent samples. However they were not found necessary in interpreting results.

TABLE 1

Dissolved oxygen before and after filtration

NUMBER	TEMPERATURE	PER CENT SATURATION			OXYGEN			SAMPLING FROM START	LENGTH SERVICE
		Top	Effluent	T-E	Top	Effluent	OT-OE		
	°C.				*p.p.m.*	*p.p.m.*	*p.p.m.*	*hours*	*hours*
1	0.8	100.8	101.3	−0.5	14.42	14.50	−0.08	15½	24
2	0.8	99.5	98.7	0.9	14.25	14.12	0.13	3	28
3	0.8	98.8	98.0	0.8	14.13	14.03	0.10	4	28
4a	0.8	99.9	99.2	0.7	14.28	14.19	0.09	2	28
4b	0.8	99.9	96.4	3.5	14.28	13.79	0.49	26½	28
5	0.8	100.6	100.6	0.0	14.39	14.40	−0.01	3	25
6	0.8	97.3	96.7	0.6	13.93	13.88	0.05	10	26
7	0.9	101.1	100.9	0.2	14.43	14.40	0.03	4	26
8	1.0	98.0	98.2	−0.2	13.95	13.97	−0.02	20	24½
9a	1.0	100.2	99.4	0.8	14.26	14.15	0.11	5	27
9b	1.0	105.41	97.0	8.4	15.00	13.80	1.20	26	27
10	1.0	103.9	99.4	4.5	14.79	14.15	0.64	4	27
11	1.0	98.0	97.8	0.2	13.94	13.92	0.02	29½	32
12	3.3	100.3	99.0	1.3	13.42	13.25	0.17	3½	23
13	4.0	99.6	98.3	1.3	13.08	12.90	0.18	25	26
14	4.0	99.8	99.2	0.6	13.10	13.03	0.07	22	23½
15	6.0	94.4	93.1	1.3	11.77	11.60	0.17		
16	6.5	95.9	93.3	2.6	11.82	11.49	0.33	2½	26
17	7.0	96.6	94.2	2.4	11.75	11.46	0.29	6	31½
18	7.0	95.1	93.4	1.7	11.56	11.36	0.20	24	30½
19	7.5	97.0	95.0	2.0	11.68	11.47	0.27	28	31½
20	8.0	96.1	94.4	1.7	11.40	11.20	0.20	28	30
21	10.0	93.0	91.3	1.7	10.54	10.35	0.19	22	29
22	21.0	90.2	85.3	4.9	8.10	7.66	0.44	8	28
23	21.0	91.7	86.8	4.9	8.10	7.74	0.36	7	29½
24	22.0	92.3	87.3	5.0	8.15	7.71	0.44	7½	25
25	22.0	93.0	86.6	6.4	8.21	7.65	0.56	22	30
26	22.0	93.9	91.1	2.8	8.25	8.00	0.25	4	27
27	22.0	96.5	91.4	5.1	8.51	8.08	0.43	12	22½
28a	22.5	92.7	88.9	3.8	8.11	7.78	0.33	4	27
28b	22.5	93.6	91.0	2.6	8.19	7.94	0.25	23	27
29	22.5	101.3	97.8	3.5	8.87	8.55	0.32	10½	22
30	22.5	97.4	92.5	4.9	8.62	8.10	0.52	4	24

One can readily see that there is a gradual increase in the amount of oxygen removed by the filter as the temperature of the applied water increases. For the purpose of making a better comparison the results were averaged over narrow ranges of temperature and are shown in table 2. The average results were then calculated to cubic centimeters per liter and to cubic feet per million gallons. The last column represents air equivalent to the oxygen, assuming that the former contains 21.0 per cent of oxygen.

What becomes of the oxygen lost during filtration? It is reasonable to suppose that some of it is used up in biological reactions in the filter bed. These reactions would be more complete as the temperature increases. Therefore, more oxygen will be removed during the summer than during the winter. Whether or not all is used in this manner has not been settled. It is unfortunate there is not a titrimetric method for the determination of nitrogen. An accurate determination of gases other than oxygen might give a better idea whether or not air actually escapes from the water during filtration in cases where air is not found in the bed on washing. The boiling out method can be used, but is rather cumbersome for making large numbers of determinations. The author hopes to perfect an apparatus for collecting any released gases from the filters. An analyses of these, if there are any, may give information as to what actually happens in the filter bed.

TABLE 2

Averaged decreases of dissolved oxygen

TEMPERATURE		OT–OE AVERAGE	OXYGEN PER LITER	OXYGEN PER MILLION GALLONS	AIR PER MILLION GALLONS
Range	Average				
°C.	*°C.*	*p.p.m.*	*cubic cm.*	*cubic feet*	*cubic feet*
0.8– 1.0	0.9	0.04	0.02792	27.9	133
3.0– 3.4	3.8	0.14	0.09772	97.7	465
6.0–10.0	7.5	0.24	0.16752	167.5	798
21.0–22.5	22.0	0.40	0.27920	279.2	1,330

Observations other than chemical indicated that although temperature may have some relation to air-binding it is not the sole cause of it. Air was occasionally present at all temperatures, although during the last two years it is most prevalent during the summer months. The reason for this can be traced to the handling of the water before filtration. The negative head under which the filter works and, as Baylis pointed out, the introduction of the first air bubbles in the filter are suggested as possible causes for air-binding. A supersaturation of air in the applied water is also conducive. For example, in the case of numbers 4b, 9b, and 10 in table 1, the reduction in dissolved oxygen is more than average at the end of the run when there is the maximum negative head or where there is a supersaturation of dissolved oxygen in the applied water.

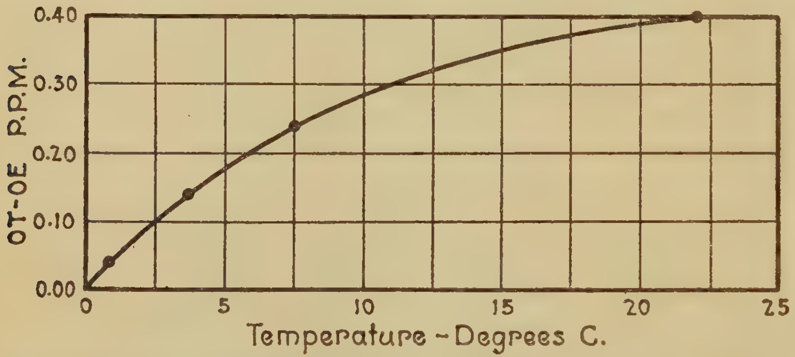

Fig. 1. Relation of Temperature to Decrease of Dissolved Oxygen by Sand Filters

A small part of oxygen determined by laboratory tests represents a large volume of air in a million gallons of water. One-tenth of a part per million of oxygen is equivalent to 330 cubic feet of air in a million gallons of water. If one is using dissolved oxygen determinations as a basis for judging the amount of air released during filtration a correction should be made for the oxygen normally removed from the water by the filter at that temperature.

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IMPOUNDED WATERS AND MALARIA

Editorial Comment

Within the past two years LePrince has called attention, in the pages of the Journal,[1] to the dangers associated with the impounding of water in large areas, in so far as such areas may bear some relationship to epidemic malaria. Although these discussions might have impressed some readers as of only academic importance, recent investigations of the problem, particularly in the southern portions of the United States, have demonstrated the important duty imposed upon water works designers in the protection of the health of populations adjacent to impounded water areas. The progress in water power development, particularly in this country in recent years, has given increased emphasis to the necessity of providing against the sharp rise of malaria during or after the completion of such impounded areas. Exactly analogous conditions may likewise be established in impounding large areas for potable water supply purposes.

In view of these warnings and suggestions by LePrince in This Journal and by other investigators in other publications, the recent observations[2] by Smillie in Alabama appear to deserve editorial comment. This investigator has had a unique opportunity to observe, over a period of three years, the relationship between impounding of water and the increased occurrence of malaria at Gantt, Covington County, Alabama. These observations extend from a year previous and two years subsequent to the impounding. In the spring of 1922 a power company began the construction of a dam across the Conecuh River at Gantt Village, with a population of about 250 people. The construction work on the dam progressed slowly during 1922, with the completion thereof requiring the greater part of 1923. The State Board of Health of Alabama established certain regulations for the procedures to be used in controlling the breeding of mosquitoes in the waters impounded. Controversial difficulties between the power company and the State Board of Health, as to the details of the application of the State regulations at the reservoir, resulted in incomplete clearings of the impounded areas at various heights and considerable raising and lowering of the water surface by the power company during the period of construction. In November, 1924, the company and the State authorities finally reached an agreement upon the methods to be used in protecting the surrounding population against mosquitoes and malaria, so that the Company agreed to lower the river to its original bed by April 1, 1925 and to comply with the State regulations before reimpounding.

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[1] Journal, January, 1926, p. 35; January, 1927, p. 31.

[2] The American Journal of Hygiene, January, 1927, vol. 7, No. 1, page 40.

The sanitary results of these engineering and diplomatic negotiations are amply set forth, without comment, in figures 1 to 6. They demonstrate the necessity of precautions on the part of the designing engineer to prevent malaria after building works for impounding water.

ABEL WOLMAN.[3]

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[3] Editor, Journal of the American Water Works Association; Chief Engineer, Maryland Department of Health.

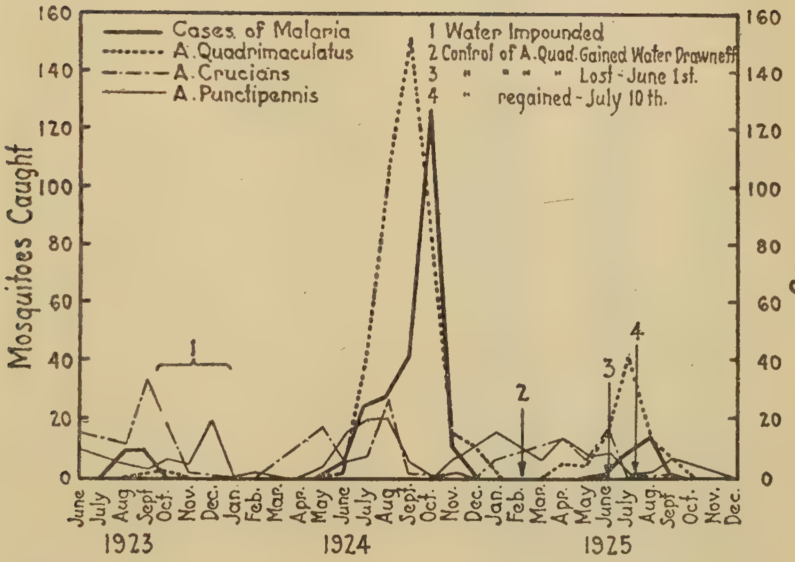

FIG. 1. ANOPHELES DENSITY AND CASES OF MALARIA IN THE GANTT AREA, ALABAMA, BY MONTHS IN 1923, 1924 and 1925

The increase in anopheles mosquitoes in 1924 followed the impounding of water without adequate mosquito control measures. The close relationship between rise in numbers of A. quadrimaculatus and increase of malaria shows that this mosquito was the principal vector.

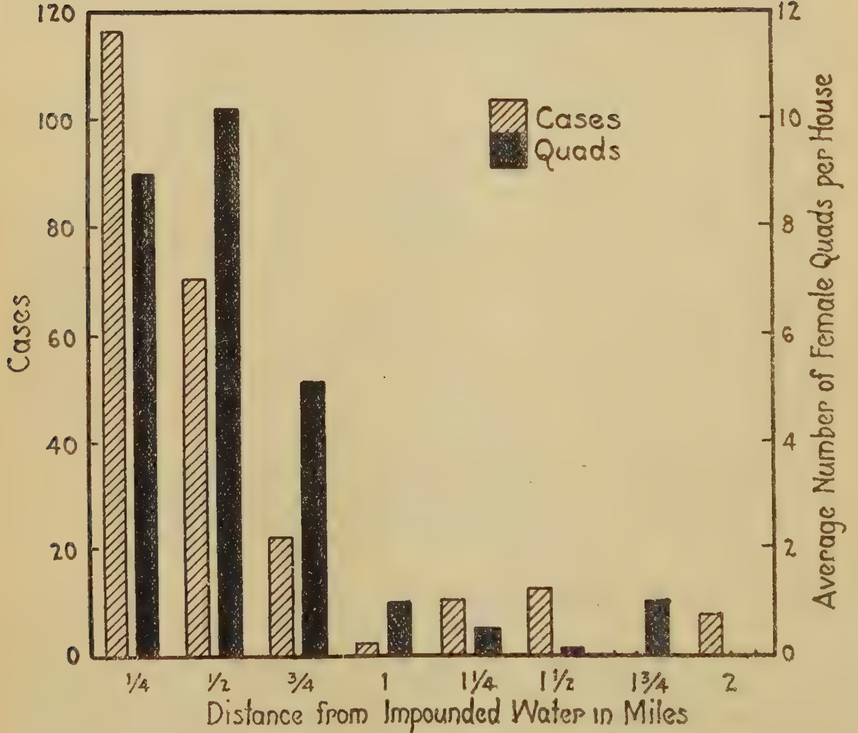

Fig. 2. Relation of Malaria Cases and of Density of Female A. Quadrimaculatus to Distance from Impounded Water

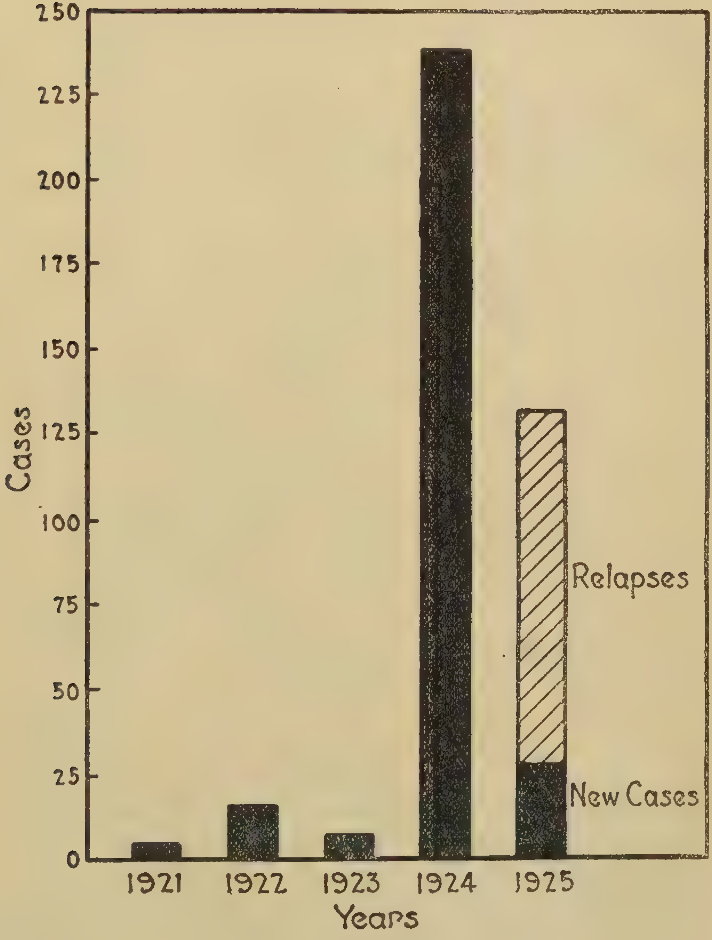

FIG. 3. YEARLY INCIDENCE OF MALARIA FOR THE GANTT AREA FROM 1921 TO 1925

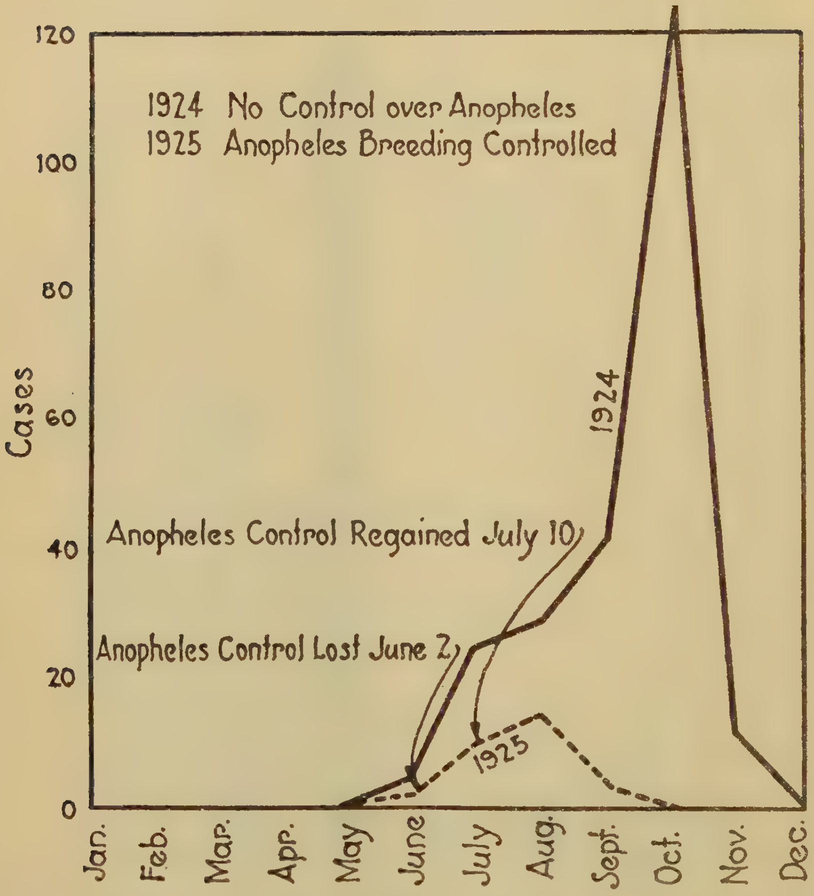

Fig. 4. Incilence of New Cases of Malaria during 1925, Compared with Incidence of Cases in 1924

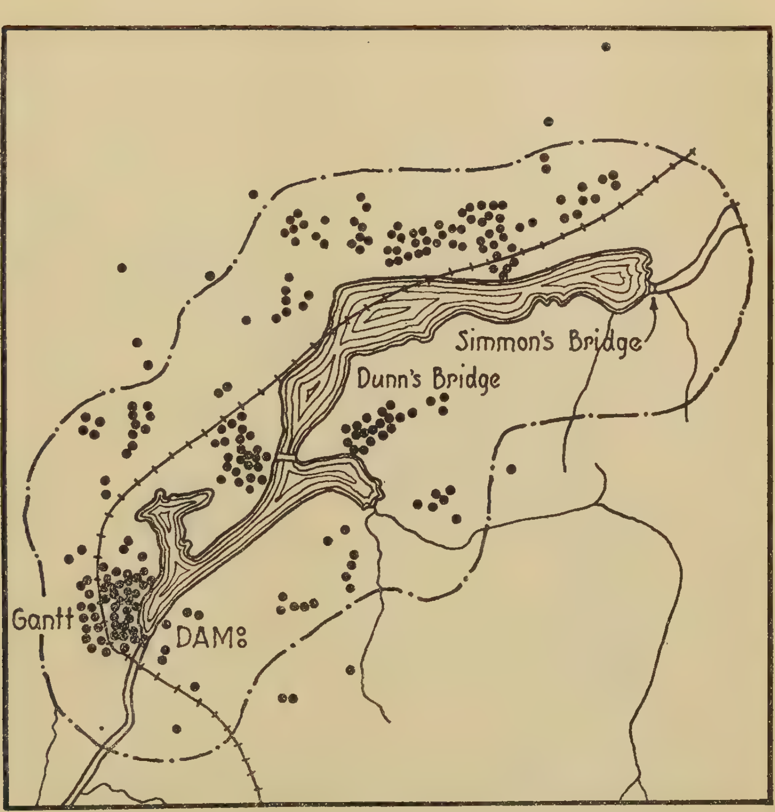

FIG. 5. EPIDEMIC OF MALARIA AT GANTT, ALABAMA

Map of impounded area, 1924. Dam to Dunn's bridge, partially cleared; Dunn's bridge to Simmon's bridge, uncleared. The line is drawn 1 mile from high water mark of the margin of the pond. Each dot represents a case of malaria.

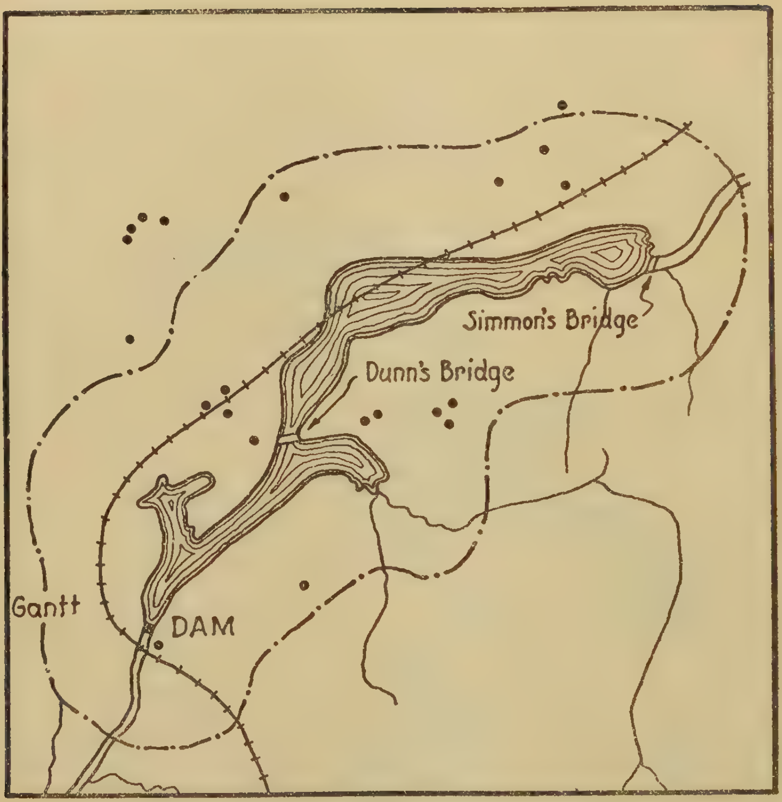

FIG. 6. DISTRIBUTION OF MALARIA AT GANTT, IN 1925

Map of impounded area, 1925. Dam to Dunn's bridge, cleared; Dunn's bridge to Simmon's bridge, partially cleared. The line is drawn 1 mile from high water mark of the margin of the pond. Each dot represents a case of malaria.

SOCIETY AFFAIRS

MONTANA SECTION

The second annual meeting of the Montana Section, was held in Billings, Montana, January 7 and 8, 1927. Mr. Willett, section president, was in the chair. The Billings city water department, of which Mr. Willett is superintendent, was host and entertained all in a royal manner. Starting with registration and an executive committee meeting Friday morning the session extended until late Saturday afternoon.

At the executive committee meeting a policy of committee organization and work during the interim between meetings, was fully discussed and agreed upon. Every member upon some committee for constructive study of various problems is the aim. That this second meeting was an extremely important and crucial one was recognized by all. We are beginning to see where our efforts can be directed to the greatest advantage to all and are all enthusiastic to get into the game.

The afternoon was given over to a visit to the Billings city water filtration plant on the Yellowstone. This was among the first of the rapid sand plants to be built in the state. It has seen continuous service since its installation and is a model of its kind. Mr. Willett explained in detail his operations and told of many difficulties met and conquered.

F. L. LaMotte gave an interesting talk and demonstration of the hydrogen ion theory and control of water purification.

Following this the visitors were taken to the "Rim Rocks" the huge natural wall of rock surrounding the city where a magnificent view of the historic Yellowstone Valley was obtained. It is here that an equestrian statue of "Bill" Hart will soon be placed. On the way up we passed "Boot Hill Cemetery" a spot replete with memories of the good old days when men died with their boots on.

The Friday evening session was given over to a discussion of the best form of organization for the municipal water department. This was led by C. A. Becraft of the Miles City water department. The discussion by practically all present was lively and showed the need of some remedies for existing conditions.

The Saturday sessions were opened by the mayor in an address of welcome, the president's response and address and routine matters of business.

We were fortunate in having Beekman C. Little, secretary of the parent association, with us for conferences and discussions. We regretted his inability to reach Billings until late Friday night but made good use of him on Saturday.

In the afternoon W. M. Cobleigh, of the State College of Agriculture and Mechanic Arts, discussed the subject of the corrosion of pipes by water within and without. The discussion which followed indicated that this was frequently met with in our territory.

Mr. Little told of the activities of the parent association and of the relation of our section to the whole organization.

By the time the dinner was concluded Saturday evening there was no dissent to the opinion that a very successful meeting had been held.

Officers elected for the coming year are: President, John Hall; City Engineer, Choteau, Montana; vice president, Jos. L. Schmit, City Engineer, Lewistown, Montana; secretary-treasurer, H. B. Foote, Helena, Montana. Lewistown was designated as the meeting place for 1928.

H. B. Foote,
Secretary.

NORTH CAROLINA SECTION

The sixth annual meeting of the North Carolina Section, convened at the Cape Fear Hotel, Wilmington, N. C., Monday, August 23, 1926. The President, J. O. Craig, presided, and H. E. Miller acted as Secretary, due to the recent resignation of Thorndike Saville.

The convention having been called to order by the President, Dr. Sullivan, Pastor of the Calvary Baptist Church of Wilmington, offered the invocation.

The convention was welcomed to Wilmington by the Hon. W. H. Blair, Mayor of Wilmington. Mayor Blair assured those present that the city of Wilmington was exceedingly proud to have them as her guests and that nothing would be left undone to make their stay an enjoyable event. He very aptly phrased it by saying: "Instead of presenting the convention the keys of the city, the gates have been torn from their hinges, our doors are wide open and we welcome you and are glad to have you with us." President Craig responded to Mayor Blair's address of welcome and spoke in glowing terms of the privilege and anticipation felt by the members of the Water Works Association for their stay in Wilmington.

At the business session of the meeting it was unanimously voted that resolutions on the death of Dr. R. H. Lewis, former Executive Secretary of the State Board of Health, be prepared by the secretary and published in the Section Journal along with a photograph.

It was also unanimously voted that pamphlets containing the report of the Committee on Steam Gauging and Forestation be printed by the Publication Committee and distributed to the members of the Legislature, members of the Section and to other interested parties.

The officers elected for the ensuing year were as follows: C. M. Grantham, President; C. E. Rhyne, Vice-President; H. G. Baity, Secretary-Treasurer; W. E. Vest, Chairman of Nominating Committee. The Water Purification Conference elected A. O. True chairman and G. F. Catlett secretary for the ensuing year.

The above were the only elective offices which were to be filled at this meeting. The Executive Board for the ensuing year is as follows: E. G. McConnell, H. G. Baity, C. M. Grantham, H. E. Miller, G. F. Catlett, J. O. Craig, C. E. Rhyne and W. E. Vest.

Durham was selected as the next convention city. A friendly rivalry developed between High Point and Durham, but since Durham had made repeated requests for this particular convention they received the greater number of votes, while High Point claimed the 1928 meeting. The convention discussed the advisability of holding future meetings in the cities in the central portion of the state in order that travel distances would be equally divided among those members who live in the extremities of the state. It was the consensus of opinion that it would be best to alternate the geographical location of convention cities between the East, Middle and West.

Suitable resolutions were prepared and read, thanking the city of Wilmington for its hospitality and the management of the Cape Fear Hotel for the many courtesies shown the members of the meeting by the hotel. The annual convention banquet, held in the ballroom of the hotel, was one of the most successful yet held and was greatly enlivened by the debate between Messrs. Maffitt and Logan, which was won by Mr. Logan.

The boat ride down the Cape Fear river to Southport tendered the convention by the Manufacturers Association was a most enjoyable event. A smoker was held aboard the steamer for the men, while the ladies were entertained at bridge and both ladies and men enjoyed the dance.

The convention was very happy to have a number of out of the state guests, who were welcomed in due and ancient form. Among these might be mentioned Beekman C. Little, of New York City; James E. Gibson, of Charleston; Mr. Bowers, of Newport News; Mr. Chapman, of Camden, S. C.; Mr. Simmons of Laurens, S. C.; and Mr. Clark of Nashville, Tenn.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of issue, and 16 to the page of the Journal.

Preliminary Index to River Surveys Made by the United States Geological Survey and Other Agencies. B. E. JONES and R. O. HELLAND. U. S. Geol. Survey Water Supply Paper 558: 108, pp., 1926. Gives data for each State, Alaska, and Hawaii, in regard to maps and profiles of streams surveyed by Federal Geological Survey, other Federal bureaus, and State organizations, with notes as to source of data, scale, contour interval, extent to which topography is shown, and other features. Areas covered by standard topographic maps of the Geological Survey are shown on insert map and another map shows in considerable detail boundaries of drainage areas in the United States.—*David G. Thompson.*

Water Power and Irrigation in the Madison River Basin, Montana. J. F. DEEDS and W. N. WHITE. U. S. Geol. Survey Water Supply Paper **560-A:** pp. 1–30, 1925. Data in regard to precipitation, stream flow, irrigation, and power possibilities in Madison River Basin. Annual water supply is more than 1,400,000 acre-feet. Capacity of power plants now installed is 18,000 horsepower, with reservoir capacity of 386,000 acre feet. Undeveloped power resources estimated at 136,000 horsepower.—*David G. Thompson.*

Water Levels in San Gabriel Valley. HAROLD CONKLIN. Map with appended text, California Division of Water Rights, 1926. A valuable map showing water level contours in San Gabriel Valley as in December, 1925, and January, 1926, with brief text describing conditions. Key wells which have been measured for more than 20 years show that in some places in December, 1925, the water level was from 4 to 241 feet lower than in 1904, although the latter year completed a drought more severe than the recent dry period. Some wells showed practically no change in level.—*David G. Thompson.*

Discharge Records of North Carolina Streams, 1889–1923. North Carolina Dept. Conservation and Development Bull. 34: 405 pp., 1925. A compilation of stream flow records for 39 years, prepared in coöperation with U. S. Geological Survey. An innovation in reporting such records is introduced in this volume, namely the publication of the mean weekly discharge for each week of the entire period covered by the record, in addition to the usual monthly discharges. For several streams graphs show weekly duration curves for average and minimum years. A map of the State shows boundaries of drainage basins, locations of gaging stations, and water power developments of more than 1000 horsepower.—*David G. Thompson.*

Principles of Rate-Making Wm. M Wherry. Jour. New Eng. Water Works Assoc., 40: 3, 249, September, 1926. Brief review of questions raised and disposed of in water-works cases since January, 1925. Fundamental principle is that company has a right to fair return on fair present value in addition to operating costs and taxes. Also customers are not to pay more or less than fair value of service rendered them. If service is poor, rate may be fixed contrary to the first principle Difficulty is encountered in determining fair present value of property Estimation of cost to reproduce system at present prices, less accrued depreciation, fairest method. Value of paving over mains is disputed. Percentage or split-inventory method may be used where there is a complete inventory record, although there is tendency to value too low. Out of 17 cases, 12 were originally valued too low by commissions; of these, 5 appealed to courts and secured full valuation; four others were subsequently correctly valued. Structural overheads have been generally accepted by the courts in figuring rates, but going values are not generally accepted due to lack of proof. Value of assembled real estate is sometimes much more than that of isolated tracts, but this fact is not often recognized. Water rights, which are peculiar to water companies, are hard to evaluate. Right of appropriation of water from lower riparian owners has a value. Depreciation is hard to determine, the straight line method being commonly used, but actual proof being more frequently required than heretofore. Excess building for expansion purposes should be liberally included. "Rate of return for water utility should be based on market value of money, the fair value of the property, the amount of the fair value over the actual investment, the financial history as to the payment of dividends, the amount of surplus invested in plant equipment, and the general history and record of financial operations and service rendered." Operating expenses have been held by different courts to include cost of rate litigations and franchises, unusual expenses due to emergency pumping, cost of changing mains due to paving, rentals for leased property, payments for water diversion, federal taxes, and increase in local taxes subsequent to rate case valuation; while, on the other hand, athletic club dues, personal fees of employees, advertising, cost of maintaining unused property, and surveys for additional water supplies have been excluded. Fees for tapping have been unfairly included in revenues. Rates should be fixed on cost analyses without discrimination. All consumers should be charged the same and services should be metered. Fire protection services can be most fairly charged on the inch-foot basis or on the capacity of the supply mains. Water company cannot be required to expand into inadequate territory without a guarantee of fair revenue. Service however must be supplied inside the franchise territory. Excuse of inadequate rates for lack of extensions not upheld when company failed to apply for higher rates.—*W. U. Gallaher.*

Some Random Notes on Water-Works Practice Abroad. C. W. Sherman. Jour. New Eng. Water Works Assoc., **40**: 3, 297, September, 1926. Average consumption in Europe is from 15–35 U. S. gallons per capita per day. Pressure in most cases is very low, especially in England where house tanks are used. Mains are chiefly of cast iron and much smaller than in America, the network pipe being about 4-inch. In Italy, pipes of asbestos and Portland cement are being used. Linings of one-half inch cement and of a combination of asphalt and ground rock are being put in pipe to prevent corrosion. Pipe patterns are not standardized. In the case of French ball and spigot type, the bell has no shoulder, the lead groove being small and semicircular, while the spigot end has a heavy bead. In order to use lighter material and localize breakage the French are shrinking rings on pipes. Corrosion and tuberculation of cast iron pipe not serious problems in France, Belgium, and Holland, but English Lake District, Wales, and Scotland have considerable trouble therefrom. Jointing compounds are not used to any extent, but joints with rubber packing rings are common. Spacing at end of pipes, about one-fourth inch from spigot end to bottom of bell, is universal practice. Pipes are laid about 3½ feet deep in England and 3 feet, or less, in France. Small pipes are gated with solid wedge type gates at each end of block while larger ones may have gates a mile apart. Hydrants are of the flush type with markers on adjoining fences or buildings. Service taps are made in top of pipe, frequently without a machine for tapping under pressure. Lead service pipes are used entirely. Meters are prohibited in London. Holland has some meters of the inferential type. London water department has a very efficient survey department for location of leaks with special gate and service men. London's new Queen Mary storage reservoir for Thames water has capacity of 8100 million U. S. gallons, has perimeter of 4 miles, and is 36 feet deep. Holland gets water from wells which must be carefully guarded from salt sea water.—*W. U. Gallaher.*

Theory and Use of Thermit Heat Units in Relieving Ice Conditions. H. T. Barnes. Jour. New Eng. Water Works Assoc., **40**: 3, 312, September, 1926. Large ice packs and frazil ice have been broken up by means of thermit. Better than dynamite because it actually burns ice with intense heat generated. Explosion wave is slow. Does not harm concrete structures, turbines, etc., in vicinity of operation.—*W. U. Gallaher.*

Head Losses in Rapid Sand Filters at Cambridge, Mass. R. G. Tyler, W. A. Danielson and M. LeBosquet, Jr. Jour. New Eng. Water Works Assoc., **40**: 3, 322, September, 1926. Results of experiments on rapid sand filters show: (1) head losses due to sand friction unimportant compared to losses due to clogging; (2) sand is graded according to size with proper washing and gradation is necessary for proper functioning of filters; (3) effective filtering stratum consists of floc layer and supporting fine sand layer; (4) below 0.5 foot sand is of slight value in removing solids; (5) small uniformity coefficient for given effective size, as is usually specified, is not so highly important, since uniform grading off is desirable; (6) uniformity coefficient of top 3 inches of sand after specified washing would be good method for specifying sand; (7)

effective size may be larger where floc is coarse, or detention period short, than when floc is peptized; (8) runs vary with coarseness of floc; (9) coarse floc is retained on surface of sand while fine floc is removed in voids; (10) sand depth may possibly be decreased, if there be rapid grading off of sand; (11) upper 0.05 foot filter surface breaks through in numerous cracks which increase effective surface area of filter; (12) negative pressure occurs first at about 0.50 foot depth and extends downward, but eventually upward to within 0.20 foot of surface; (13) greater positive head might minimize air binding and give longer runs; (14) sudden increases in positive head compacted sand giving sudden increases in head loss; (15) aluminum sulfate floc more completely removed by sand surface than sodium aluminate floc; (16) effective size better method for comparing filter sands than surface modulus or specific surface.—*W. U. Gallaher.*

Purpose of the Cast-Iron Pipe Publicity Bureau. T. F. WOLFE. Jour. New Eng. Water Works Assoc., 40: 3, 345, September, 1926. Publicity to promote new water works systems, encourage proper design of water works, interest citizens in municipal water works systems, and point out advantages of cast-iron pipe. Bureau also collects data on failures etc. and has a technical committee to work out specifications for cast-iron pipe. A handbook is soon to be published.—*W. U. Gallaher.*

Compensating Reservoirs and Diversion of Water. C. M. SAVILLE. Jour. New Eng. Water Works Assoc., 40: 3, 352, September, 1926. Most equitable method of settlement for diversion of water is by compensation in kind by methods which will simulate as nearly as possible the average dry year run-off of stream which has been diverted. Lower riparian owners usually prefer water to money settlement, a price being hard to set in most cases. After court action, three billion gallon reservoir has been built by City of Hartford on branch of Farmington River to compensate for water diverted from one of its tributaries for city use. Gates are operated by city employees under direction of riparian owners. Arrangement has been very satisfactory to all parties. X. H. Goodnough in 1922 established principle of utilizing wasted flood flow for industrial purpose. Providence, R. I., in 1925 instituted method of daily allocation of water from its water supply reservoir to mills below as part payment for diversion damages, allocation decreasing each year. Appendix I. Data on diversion settlements. Appendix II. Agreement between City of Hartford and lower riparian owners. Appendix III. Second agreement between above parties specifying method of operation, rights of each party, etc.—*W. U. Gallaher.*

Centrifugal Pump Specifications Should be Complete. C. C. BROWN. Power Plant Engineering, 30: 18, 996, September 15, 1926. "Characteristics should be studied for each installation and all terms used in specifications defined." In specifying performances and comparing designs define commonest terms, such as 'power' and 'efficiency.' Efficiency depends on favorable combination of head, capacity, and speed; the smaller the impeller and the higher the rotative speed, the higher the efficiency. Best to have high average efficiencies over wide variations of head and capacity. Brake horsepower curves at maximum at rated head and capacity. Prime importance in motor driven pumps.—*W. U. Gallaher.*

Flow Measurements With The Flat Plate Orifice. Power Plant Engineering, 30: 18, 997, September 15, 1926. "Simplified formulae and coefficients facilitate use of flow meter for temporary or portable use in air, steam, and water measurements." Principle of flat plate orifice same as that of venturi tube and of flow nozzle. Monel metal best material for orifice. Two pressure taps should be exactly located, preferably in side of pipe, the upstream tap one pipe diameter above orifice and downstream tap at "vena contracta," location varying with orifice ratio. Inches of water most convenient unit to use for differential head. Instruments easily recalibrated and new constants calculated. Two sets of calibration figures given, one for steam and water, and one for air. For compressible fluids, pressure differential should be kept below 1.5 per cent of initial pressure. Keep orifice installation 10 or 12 pipe diameters from elbows and bends.—*W. U. Gallaher.*

Motor Operated Valves Aid Plant Operation. Power Plant Engineering, 30: 18, 1001, September 15, 1926. Principal details of valves and controls and costs of installing are given, and several interesting applications are discussed. Valves should work perfectly, particular attention being paid to stems and their connection with disc. Friction minimized by ball bearings while machined guides in body and disc are essential. Valve should be protected with shear pin or adjustable friction clutch. Motor drive consists essentially of motor, reduction gears, and limit switch. Provision should be made for hand operation; usually by a clutch arrangement. Controls may be at numerous points, or at a master station, and there should be valve opening indicators. Closing time of valves depends on size of valve, pressure involved, and desire of user. Higher closing speed means less torque available.—*W. U. Gallaher.*

De-Concentration of Water Effects Marked Savings. J. O'Brien. Power Plant Engineering, 30: 23, 1275, December 1, 1926. Deconcentration of boiler water by addition of soda ash and filtering has reduced renewals from two per year to one in four years and boiler washings from one in 105 days to one in 35 days, with a net saving of $1,402.96 per year on an investment of $700.—*W. U. Gallaher.*

Trend Toward Better Water Supplies. Wellington Donaldson. Engr. & Contr., 65: 495–7, 1926. Muni. & County Eng., 71: 109–12, 1926. A general discussion of some of the recent developments for water supplies.—*C. C. Ruchhoft.*

Water Hyacinth. Anon. Engr. & Contr., 65: 514, 1926. Twelve acres of water hyacinth were removed from a lake with a crane equipped with a special fork bucket with excellent success by the Park Board of St. Petersburg Fla.—*C. C. Ruchhoft.*

Conservancy Districts and Their Possibilities. PAUL HANSEN. Engr. & Contr., 65: 539–42, 1926. The Illinois legislature created a law authorizing the establishment of conservancy districts having a unified control of the pollution of an entire river system and permitting a unified development of a water supply. The conservancy district may build sewage disposal works from the proceeds of bond issues payable out of general taxation spread over all of the assessable property of the district. Water supplies developed by the district are placed on a self-sustaining business-like basis, for the water must be sold by meter and rates must be fixed to pay all operating expenses and fixed charges, and all earnings can be used only for improvement or reduction of rates. The conservancy district is governed by five trustess with overlapping terms appointed by county judges. A conservancy district has been formed for the Fox Valley.—*C. C. Ruchhoft.*

Unique Features of Omaha Pumping Station and Filtration Plant. Anon. Engr. & Contr., 65: 565–67, 1926. The Florence Pumping Station of the Metropolitan Utilities District at Omaha, Nebr., is equipped with two Worthington split casing double suction volute pumps connected in series with a capacity of 50,000,000 gallons per day against a head of 280 feet, and driven by a 3000 h.p. G.E. condensing type steam turbine. In the two pumping stations at Omaha, five water wheel driven pumps are used. The water wheel driven wash water pumps deliver 850 gallons per minute against a 60-foot head at 450 r.p.m. and require 550 gallons per minute at a net head of 190 feet for their operation. The water required to operate the pumps is discharged into the wash water reservoirs into which the pumps also discharge. It is claimed that this method of pumping wash water is $2,500.00 per year under any other method.—*C. C. Ruchhoft.*

New Well System at Havelock, Neb. FRED C. HALL. Engr. & Contr., 65: 576–7, 1926. The old well system consisting of six 6-inch wells was only able to produce 320 gallons per minute which was not sufficient for the needs of the city. Ten test wells were drilled and the one tapping the best water bearing gravel was chosen as the site for the permanent well. A 38-inch iron casing and an 18-inch inner casing and iron screen was put into the new well and gravel was put into the space between the two casings. The completed well produced 610 gallons per minute.—*C. C. Ruchhoft.*

Scientific Control of Alum Feed. A. B. CAMERON. Engr. & Contr., 65: 567, 1926. The installation of a venturi tube meter on the raw water line and of two Gaunt type dry feed machines in the old rapid sand filtration plant at Bucyrus, Ohio, reduced the alum consumption from 100 to 60 tons per year, or to less than 2 grains per gallon, with no decrease in efficiency of the plant and effected a saving of 90 per cent of the investment the first year.—*C. C. Ruchhoft.* (*Courtesy Chem. Abst.*)

Water Softening at Columbus, Ohio. CHARLES P. HOOVER. Entr. & Contr., 65: 498–500, 1926. The split treatment process of water softening, in which an over treatment with lime and soda ash is given to as large a portion of the hard water as possible to get the maximum reduction in hardness and the excess lime and soda ash then neutralized with hard water, is used at Columbus. This process is more effective than the ordinary method though not so effective as, but cheaper than, overtreatment. 26.4 m.g.d. were softened from 298 to 92 p.p.m., a reduction of 69 per cent, and filtered. The cost of lime, soda ash, alum and chlorine was $20.98 per million gallons.—*C. C. Ruchhoft.* (*Courtesy Chem. Abst.*)

Algae Growth in Impounding Reservoirs. A. B. Cameron. Engr. & Contr., 65: 618–20, 1926. Dosing impounding reservoirs once or twice each summer month with from 0.25 to 0.40 p.p.m. of copper sulphate was effective in preventing short filter runs, use of excess wash water, and bad tastes at Bucyrus, Ohio. The necessity of dosing the reservoirs was determined by the noting of litteral organisms in the plant, length of filter runs, and frequent microscopical examination.—*C. C. Ruchhoft.* (*Courtesy Chem. Abst.*)

How Sun Spots Affect the Level of the Great Lakes. Halbert P. Gillette. Engr. & Contr., 65: 466–7, 1926. Gillette explains that the 3 per cent more heat which is emitted from the sun during years of greater sun spot activity results in greater evaporation of sea water which later on results in greater rainfall on the continents; and presents a chart showing the relationship between sun spot frequency and lake levels.—*C. C. Ruchhoft.*

Excavation in Water Bearing Sand. R. C. Wilson. Engr. & Contr., 65: 555–8, 1926. The site of the pumping station and part of the filter plant for Palm Beach and West Palm Beach was occupied by Lake Clear. A dike of fine sand was built around this site by means of an electrically driven hydraulic dredge. A 12-inch centrifugal pump, delivering 3 million gallons per day from three existing wells tapping a coarse shell stratum about 90 feet under the surface of the lake, was used in draining this area. This system of subsurface drainage very successful and saved much time and money.—*C. C. Ruchhoft.*

Los Angeles Raises Water Rates for Domestic Use and Irrigation. Eng. News-Rec., 97: 94, July 15, 1926. Following new schedule per 100 cubic feet of water consumed in one month was recently adopted in Los Angeles: First 10,000 cubic feet, 13 cents; next 40,000, 11 cents; next 50,000, 9 cents; all in excess of 100,000, 7 cents, provided that minimum monthly rates shall not fall below the following: for $\frac{5}{8}$-, $\frac{3}{4}$-, and 1-inch meters, $1; 1½-inch, $1.50; 2-inch, $2; 3-inch, $3; 4-inch, $4; and 6-inch, $6. The former rate was 10 cents per 100 cubic feet compared with average maximum rate of 18 cents for 183 of the largest and most representative American cities.—*R. E. Thompson.*

Muskogee, Okla. Eng. News-Rec., 97: 108–9, July 15, 1926. Changing conditions, due to tourists and campers throughout the watershed of Grand River, from which city water supply is derived, are making necessity of filtration more and more pronounced. Proposed $225,000 bond issue for this purpose was rejected by citizens last year. Turbidity is less than 20 for 5 months of year. Total settling storage capacity is 10 million gallons, equivalent to 3 days' supply. Water is treated with 6 pounds of chlorine per million gallons. Services are metered, bills being rendered monthly.—*R. E. Thompson.*

Public Water Supplies in Haiti. Eng. News-Rec., 97: 109, July 15, 1926. Brief data on public supplies in Haiti. Ten municipalities, including Port au Prince and Pétionville, which have joint works, have public supplies. In addition, the Government has sunk 41 wells in 13 towns and villages.—*R. E. Thompson.*

Progress and Methods in the New Cascade Tunnel, Great Northern Railway. Eng. News-Rec., 97: 100–1, July 15, 1926. Progress on tunnel outlined briefly and power and tunneling equipment and character of ground described.—*R. E. Thompson.*

Removing Mud Balls from Filter Sand. MARTIN E. FLENTJE. Eng. News-Rec., 97: 369, 1926. Mud balls in filters at Oklahoma City, Okla. were removed by passing the sand through ordinary sand jet discharging against filter wall at cost of $20 per filter. A partial analysis of the balls, which were due to inadequate washing and insufficient carbonation of the lime-softened water being treated, was: moisture 18, acid soluble material 9.5, ignition loss 0.4, and residue 72.1 per cent.—*R. E. Thompson. (Courtesy Chem. Abst.)*

Chlorination of Water. L. H. ENSLOW. Pub. Health Eng. Absts., January 30, 1926. From Chem. Abst., 20: 1290, April 20, 1926. Modern applications of chlorine to the destruction of bacterial life, algae prevention, oxidation of sulfur gases and iron, and in taste and odor prevention are discussed.—*R. E. Thompson.*

Maintenance and Operation of Water Supply Works. W. H. DITTOE, et al. Am. Jour. Pub. Health, 16: 136–9, 1926. From Chem. Abst., 20: 1291, April 20, 1926. Pollution of streams is making demand for greater efficiencies in water purification. More careful control by technical service and by state laboratories is advocated.—*R. E. Thompson.*

Antimicrobial Properties of Various River or Sea Waters. Bacteriophage Power. F. ARLOING, SEMPE and CHAVANNE. Bull. Acad. Med., 43: 7 (French); Pub. Health Eng. Absts., Jan. 30, 1926. From Chem. Absts., 20: 1291, April 20, 1926. Evidences of anti-microbial action of certain river or sea waters have been found. Lytic action of these waters is attributed to presence of multivalent bacteriophage, rather than to nonspecific causes.—*R. E. Thompson.*

Purification of Boiler Feed Water. WM. E. SMITH. Facts about Sugar, 20: 1168–9, 1925. From Chem. Abst., 20: 1291, April 20, 1926. Proper cylinder lubrication and efficiency of various types of equipment for removing oil are discussed.—*R. E. Thompson.*

Verdict in Polluted Water Case. JOHN W. S. MCCULLOUGH. Pub. Health Jour. (Can. Pub. Health Assoc.), 17: 386–7, 1926. During autumn of 1925 outbreak of typhoid fever occurred in city of Owen Sound, Ont., as result of pollution of water supply, and resident who contracted typhoid fever was recently given judgment for $2,000 and costs against the city. Provincial Board of Health had consistently urged that supply be chlorinated since a previous outbreak in 1916.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

The Water Supply of Vienna and the Possibility of Its Extension. FRANZ SCHÖNBRUNNER. Gas u. Wasserfach, 69: 85–9, 1926. From Chem. Abst., 20: 1124, April 10, 1926. Discussion of hydrology of vicinity.—*R. E. Thompson.*

Chemical and Chemicophysical Researches on Three Mineral Waters of Aganano (Naples). F. ZAMBONINI, G. CAROBBI and V. CAGLIOTI. Ann. chim. applicata, 15: 434–74, 1925. From Chem. Abst., 20: 1125, April 10, 1926. Composition and various physical and chemical constants given for three mineral waters. Methods of analysis included.—*R. E. Thompson.*

Turbidimeter for Accurate Measurements of Low Turbidities. J. R. BAYLIS. Ind. Eng. Chem., 18: 311–2, 1926. From Chem. Abst., 20: 1151, April 20, 1926. Simple apparatus described in detail for comparing turbidity of liquids with that of samples of known turbidity. Known standards are determined with Jackson candle turbidimeter. Method described readily detects turbidity of 0.1 p.p.m., but is accurate only for turbidities less than 2.—*R. E. Thompson.*

Vary Mix Design for Concrete to be Used at Different Ages. R. T. GILES. Eng. News-Rec., 97: 510–1, 1926. Results of comparative tests of concrete made with and without accurate control of water are given. With accurate control strength was greater by 77 per cent at 7 days and by 30 per cent at 28 days. In a series using fine aggregate only, of 21 gradations, the 7-day strengths were higher in every case with accurate control, while in some cases equal strengths were obtained at 28 days. One-year specimens will be tested in each series. Conclusion drawn from the experiments include (1) that fineness modulus is not a true measure of gradation but an indication only, and (2) that for ultimate strength accurate control of fine aggregate is of much more importance than accurate control of water.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

The Production of Metal Coatings on Iron. KRÖHNKE. Gas u. Wasserfach, 69: 21–4, 48–52, 1926. From Chem. Absts., 20: 1049, April 10, 1926. Description with extensive bibliography of electrolytic, spray, vapor condensation, and molten bath processes for producing coatings of tin, zinc, lead, nickel, copper, cobalt, chromium, etc., on iron.—*R. E. Thompson.*

Chloramine Treatment of Water in the Field. C. H. H. HAROLD. J. Roy. Army Med. Corps, 46: 115–9, 1926. From Chem. Absts., 20: 1124, April 20,

1926. In field tests mono- and dichloramine gave satisfactory water with better taste than did chlorine.—*R. E. Thompson.*

The Significance of Bacteriophage in Surface Water. LLOYD ARNOLD. Am. Jour. Pub. Health, 15: 950, 1925. From Chem. Absts., 20: 1125, April 20, 1926. Surface waters containing a high degree of domestic sewage contain bacteriophagic substances in direct proportion to amount of pollution. These phages cause lysis of pathogenic bacteria, thus reducing probability of epidemics. They also influence bacteriological examination for pathogens in these waters. Use of bacteriophages in filtration is suggested.—*R. E. Thompson.*

NEW BOOKS

Public Ground Water Supplies in Illinois. G. C. HABERMEYER. Ill. State Water Survey Bull., 21: 710 pp., 1925. The greater part of this voluminous report consists of detailed descriptions of nearly 400 ground water supplies in Illinois, distribution of which is shown on a map of the State. For most supplies there are data in regard to history of the systems, pumping station equipment, number of services, and meter rates. The well systems are described in somewhat greater detail, with well logs where available, notes on yields and drawdown, and miscellaneous information. For practically every supply there are one or more chemical analyses, expressed in three forms, namely determinations of elements or radicals in parts per million, and hypothetical combinations in both parts per million and grains per gallon, with notes on the effect of the water on service fixtures. Some unusual conditions to be discovered by a study of the report may be mentioned. One well, at Aledo is 3165 feet deep, and many wells are from 1000 to 2000 feet and more. Although the yield of rock wells in most localities ranges from only a few gallons a minute to a few hundred, at Aurora wells in excess of 2200 feet deep yield 1000 to 1400 gallons a minute and a 1503-foot well at Rockford yields 1400 gallons a minute. At the latter place 2.75 m.g.d. are obtained by pumps set in a shaft 79 feet below the station floor, with tunnel connections to eight wells. The water in many localities is rather highly mineralized and hard. Many of the systems supply water with total solids in excess of 1000 parts per million and a few, with even more than 2000 parts. Water containing total solids as high as 5021 parts per million apparently was used for some years as the public supply for Barry, and part of the supply for Mount Sterling contains about 3300 parts per million. Total hardness in a majority of places is probably between 250 and 500 parts per million, reaching as high as 850 parts per million at Western Springs, with total solids of 1053, and as low as 52 parts at Bureau, where the total solids are 1931 parts per million. Water from an unused well at Flora contained 61,026 parts per millon of total solids and 6946 parts of total hardness. Unfortunately the report does not contain any general summarizing of facts relating to various phases of ground water development in different parts of the State, such as distribution of the principal water-bearing formations, depth to, yield of, and quality of water obtained from them in different localities. Despite the lack of a summary, however, the report will prove of great value; indeed its full worth may not be realized until some years hence, when, in planning for additional supplies, data will be needed in regard to the effects of past pumping—data the value of which town officials often fail to realize and do not preserve. The Illinois State Water Survey has performed a useful service in recording so much data in a form easily available for future use.—*David G. Thompson.*

Waterworks Handbook of Design, Construction and Operation. Compiled by Alfred Douglas Flinn, Robert Spurr Weston and Lathrop Bogert, Third Edition, 1927. McGraw-Hill Book Co., Inc. The first edition of this book was published in 1916. From the standpoint of appearance and serviceability the new volume is an improvement over the first edition by the use of maroon colored buckram covers in place of the flexible dark blue binding.

In preparing the third edition the authors have so broadened the scope of the original text as to make it of value in other branches of engineering outside the water works field. It is still, however, primarily a book for waterworks men, but the added material therein enhances its value to them. The text is arranged in logical sequence as in the earlier additions by grouping under natural headings, as: Sources of Water Supply; Collection of Water; Transportation and Delivery of Water; Distribution of Water; Character and Treatment of Water and Hydraulics and Materials. This arrangement is most convenient for ready reference, since the topics discussed under each heading are similarly arranged along natural lines.

To keep abreast of the advance made in the waterworks branch of engineering practice during the past ten years the authors have added considerable new material to the book and rewritten and rearranged other parts. Some of the text in the earlier editions has been omitted. The volume is full of pertinent and valuable information not alone to the practising engineer, but to the non-technically trained personnel of the water department.

Since it is impossible to include in one volume all the valuable material in the waterworks field the authors have placed at the end of each chapter extensive bibliographies so that the reader, should he desire to delve deeper into any of the many phases of this branch of engineering, has at his disposal a large number of references as a guide for further research.—*George L. Hall.*

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THE INDIANAPOLIS WATER COMPANY RATE CASE[1]

BY JOS J. DANIELS[2]

In October, 1924, Judge Geiger, sitting in the United States District Court for the District of Indiana, at Indianapolis, in a suit brought by the Indianapolis Water Company against the Public Service Commission of Indiana, issued a permanent injunction against the enforcement of certain rates theretofore prescribed by the Commission, on the ground that those rates were not sufficient to yield the Water Company a reasonable return upon the fair value of its property and therefore were confiscatory and in violation of the Water Company's rights under the 14th Amendment to the Federal Constitution. The case was appealed by the defendants to the Supreme Court of the United States and was argued before that court last April. On November 22, 1926, the Supreme Court handed down its opinion, written by Mr. Justice Butler, affirming in all respects the decree of the District Court. I have been asked to comment today on the salient features of that decision.

I think it may fairly be said that the case is, and will be for some time to come, a land-mark in the law relating to the valuation of utility properties for rate-making purposes. It certainly is so regarded by the bar generally and by the utilities. Almost every day, and certainly on an average of once a week, our office receives a request for copies of the Water Company's brief or of the printed record in the case. You may be interested to learn that counsel for the railroad companies, many of whose properties are approaching a final valuation by the Interstate Commerce Commission regard the case as having an extremely significant bearing on their present problems.

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[1] Presented before the Indiana Section meeting, February 18, 1927.

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Much that is inaccurate and misleading has been written and said about the decision. Like any other court decision dealing with complicated details and difficult legal questions, the decision must be carefully studied in order to be correctly understood and explained. I shall not discuss the erroneous statements that I have seen and heard concerning the case, but I shall endeavor to give you, concisely and accurately, the questions of law which the case decides.

The opinion discusses and passes upon seven legal propositions relating to the valuation of utility properties for rate-making purposes. I shall take these up in substantially the order in which the Supreme Court decided them.

I. HOW IS THE PRESENT VALUE OF A UTILITY PROPERTY TO BE ASCERTAINED?

At the outset, it should be kept in mind that in all cases where property, or its use, is to be taken for the benefit of the public, the main question to be settled is: What is the "present value" of the property? No one contends that any value other than the *present value* is to be ascertained and declared. If the property be real estate, and therefore has a market value, the present market value is the present value to be ascertained and declared. If it is a public utility plant made up of many parts, which plant as a whole has no *market* value, the simple rule of market value cannot be applied, and in such cases, the law, by the courts, lays down rules, which the fact-finding tribunal—court or commission—must follow in determining what is the "present value" of the property that must be found and adjudged. In the Indianapolis Water Company case opinion the Supreme Court has, I believe, clarified those rules and made them more explicit than in any of its previous opinions on this subject. It has been said that the opinion holds unqualifiedly that present value is to be ascertained on one basis only, viz., the basis of the cost of reproduction new at present prices, less depreciation, if any; in other words, that so-called "spot reproduction cost" measures, and is the only measure of, present value. The opinion does not so hold. But it does lay down, more definitely than the court had done in any of the prior rate cases, certain rules and guides to the ascertainment of present value, and these rules, taken together, will, if properly applied in any given case, lead to a correct determination of what the Supreme Court thinks is present value. These rules may be summarized as follows:

Original cost is a fair measure of present value if, *and only if*, there has been no substantial change in the level of wages and prices since the plant was originally constructed. For example, the present value of a plant constructed a year ago may fairly be measured by its actual cost, for there has been no substantial change in price levels in the past year, but, the Supreme Court says, original cost has no pertinency at all in determining present value when there has been a substantial change in the level of wages and prices since the construction of the plant. In ascertaining the value of a plant in 1927, the Supreme Court would reject as irrelevant evidence of its cost in 1907.

Spot reproduction cost, as I have said, is not the *only* measure of present value. It is the measure of present value in the absence of proof of facts requiring some departure therefrom. What are such facts? They are the facts adduced with reference to the probable level of prices and wages during a reasonable period in the immediate future. The opinion states: "In the light of all the circumstances there must be an honest and intelligent forecast as to probable price and wage levels *during a reasonable period in the immediate future.* In every confiscation case, the future, as well as the present, must be regarded." For illustration, suppose that the present spot reproduction cost of a property is $1,000,000; but proof is adduced that the trend of prices is unmistakably downward and will, so far as can reasonably be foreseen, continue so for at least two or three years. The Supreme Court, in such a case, would sustain, as non-confiscatory, a present-value finding of less than $1,000,000. The converse would necessarily be true, if there was clear proof of a definite upward trend in wage and price levels But if there is no proof of a trend either way for a reasonable future period, then present construction cost is the fair measure of present value. The Court says: "If the tendency or trend or prices is not definitely upward or downward, and it does not appear probable that there will be a substantial change of prices, then the present value of lands, plus the present cost of reconstructing the plant, less depreciation, if any, is a fair measure of the value of the physical elements of the property." Thus there must be in every case more than a mere slapping of the yard-stick of spot reproduction prices to the plant under evaluation. A common-sense and good faith forecast of "probable price and wage levels" for the next few years must be applied to the present reconstruction figures. The result will be present value.

The Supreme Court had—at least many of us thought that it had—laid down substantially the foregoing rules in the Southwestern Bell Telephone Company and the Bluefields Water-Works case, decided in the spring of 1923. But following closely on these last two cases came the Georgia Railway and Power Company case, which many commissions and municipalities and others felt denied the logical implications of the Southwestern Bell and the Bluefields decisions and left the Supreme Court's position still undefined and uncertain on the question of the weight to be given to testimony of present reproduction cost and original cost figures. The Indianapolis Water Company case is the first case since the three above-mentioned to present squarely to the Supreme Court the question of the ascertainment of present value. The decision is therefore especially significant and note-worthy, and I think it will be agreed by every fair-minded person who studies the opinion, whatever his personal leanings and affiliations may be, that the decision lays down the rules which I have briefly stated above, on the subject of the correct method of finding the present value for rate-making purposes of a property devoted to the public service.

May I point out, briefly, before I leave this subject, one fact that I think has been generally over-looked in contemporary discussions of the rule of present value? Although it has been useless for years, in the light of many Supreme Court decisions, to argue for original cost as a measure of present value where there has been a substantial change in price and wage levels, and although it is equally useless, in the light of the Indianapolis Water Company decision and other Supreme Court cases, for the alleged protagonists of the peoples' interests to inveigh against the importance attached to reproduction cost under the rules that I have just stated, it may nevertheless be interesting to know that the courts first rejected "original cost" as a measure of present value, and first sanctioned the use of spot prices as evidently though not necessarily controlling, at the instance and urging, not of the utilities, but of the consumers. In the 1890 decade the courts had before them cases involving the valuation for rate making purposes of railroads and other utilities constructed in the days of high prices following the Civil War. The utilities desired rates based upon those high prices and therefore argued for original cost. The consumers declared the idea of original cost to be anathema and urged upon the courts the common-sense doctrine of present value, based on the declining prices of the nineties. Their arguments prevailed, as shown by the following brief excerpts from two cases on this subject (San Diego Company against National City, and San Diego Company against Jasper), decided by the Supreme Court in 1899 and 1903 respectively. I quote from those decisions:

> The contention of the appellant in the present case is that in ascertaining what are just rates, the court should take into consideration the cost of the plant, the cost per annum of operating the plant, including interest paid on money borrowed and reasonably necessary to be used in constructing the same, the annual depreciation . . . . and a fair profit to the company . . . . . Undoubtedly all these matters ought to be taken into consideration and such weight be given them . . . . as under all the circumstances will be just to the company and to the public. The basis of calculation suggested by the appellant is, however, defective in not requiring the real value of the property . . . . to be taken into consideration. . . . . The property may have cost more than it ought to have cost and its outstanding bonds for money borrowed may be in excess of the real value of the property. (*San Diego Co. v. National City*, 174 U. S. 179, 19 Sup. Ct. Rep. 804.)

And the following:

> It is no longer open to dispute that under the Constitution "what the company is entitled to demand . . . . is a fair return upon the reasonable value of property at the time it is being used for the public. . . . . That is decided, and is decided as against the contention that you are to take "the actual cost of the plant, annual depreciation, etc., and to allow a fair profit on that footing over and above expenses." . . . . The only evidence in favor of a higher value in the present case is the original cost of the work, seemingly inflated by improper charges to that account and by injudicious expenditures. . . . . In this way the appellant makes the value over a million dollars. No doubt cost may be considered and will have more or less importance according to circumstances. In the present case it is evident . . . . that it has very little importance indeed. (San Diego Co. v. Jasper, 189 U. S. 439, 23 Sup. Ct. Rep. 571.)

And the court then proceeded to hold that the present fair value of the plant was not in excess of $350,000, against the million dollar figure urged by the Company in that case on an original cost basis.

But as you all know conditions have altered materially since the 1890's. As Shakespeare quaintly puts it "the whirligig of time brings in his revenges," and with the reversal of conditions brought about by the World War, the people's representatives have been blind to what was so evident to them in the 1890's, the fairness and virtue of the reproduction cost theory. In the heat of conflict there is necessarily a tendency to take a short perspective in these matters, but if one takes for a moment the longer view it is not difficult to visualize the public in the 1940 decade praising the Supreme Court for not having yielded to the blandishments of the "original cost" theory in the 1920's. And, after all, how many people who built, let us say, rental properties in 1910, base their rentals today on what the properties cost them? They charge rents based on the present value of the properties. In principle this is precisely what the Supreme Court has said that the utilities are entitled to do. So much for the Supreme Court's ruling on the rules for ascertaining present value in the Indianapolis Water Company case.

II. WHAT IS A REASONABLE RATE OF RETURN ON THE FAIR PRESENT VALUE OF UTILITY PROPERTY?

Here, again, there has been some misconception of the Indianapolis Water case opinion. The Supreme Court did not fix 7 per cent as the maximum. It said that the evidence was "more than sufficient to sustain" a 7 per cent return and that "recent decisions support a higher rate of return" and it cited, among the ten decisions supporting a higher rate of return, several cases allowing 8 per cent. But the Court did not find it necessary, upon the record before it and the state of the issues, to go further than to decide that a reasonable rate of return was "not less than 7 per cent." The Court did, however, state clearly that in any utility case the rate of return cannot fairly be measured by the cost of bond money to the company. The Court said:

> It is obvious that rates of yield on investments in bonds, plus brokerage, is substantially less than the rate of return required to constitute just compensation for the use of properties in the public service. Bonds rarely constitute the source of all the money required to finance public utilities. And investors insist on higher yields on stock than current rates of interest on bonds. Obviously, the cost of money to finance the whole enterprise is not measured by interest rates plus brokerage on bonds floated for only a part of the investment.

Thus the case may fairly be cited to sustain the proposition that the rate of return depends upon "the cost of money to finance the whole enterprise."

III. MUST THERE BE IN THESE RATE CASES AN ALLOWANCE FOR WORKING CAPITAL AND MATERIALS AND SUPPLIES?

The Supreme Court in the Indianapolis Water Company case answers this question in the affirmative, in a short paragraph. It was contended by the appellants that the company was entitled to no working capital allowance because it could get its necessary working capital from pre-payments by consumers. The Court's decision, approving the allowance for working capital, rejects this contention.

IV. IS A UTILITY IN A RATE CASE ENTITLED TO AN ALLOWANCE FOR WATER RIGHTS, UPON PROPER PROOF OF THEIR EXISTENCE?

The Supreme Court holds unequivocally that it is, thus reaffirming the position that it took on this question many years ago and from which it has never departed.

V. GOING VALUE

The opinion of the Supreme Court, definitely, I think, disposes of the contention, which has been urged at various times and in various cases in the last few years, that no allowance for going value is permissible in a rate case. This argument was based—unsoundly, it is now clear,—on the Galveston and Houston cases in the Supreme Court. Those cases did reject allowances for going value, but they rejected them because the companies had attempted to base the calculation of their going value on past losses. In the Indianapolis Water Company case the Supreme Court cited several of its own earlier decisions as sustaining an allowance for going value and laid down the rule upon this subject in the language of the Des Moines gas case as follows:

> That there is an element of value in an assembled and established plant doing business and earning money, over one not thus advanced, is self-evident. This element of value is a property right and should be considered in determining the value of the property, upon which the owner has a right to make a fair return.

The court in its opinion does not attempt to lay down any rule-of-thumb for calculating the proper amount of going value in all cases but it does make some comments as to the amount properly allowed for this item to the Indianapolis Water Company which are perhaps significant as indicating generally the Court's views on this subject. After pointing out that the Commission had allowed for both water rights and going value an amount less than 6 per cent of the value of the physical properties found by the Commission, the Supreme Court says emphatically:

> Having regard to the character of the system, that amount is clearly too low. . . . . The evidence is more than sufficient to sustain 9.5 per cent for going value. And the reported cases showing amounts generally included by commissions and courts to cover intangible elements of value indicate that 10 per cent of the value of the physical elements would be low when the impressive facts reported by the commission are taken into account.

It would therefore seem reasonably safe to believe from the opinion in the Indianapolis Water Company case that in any case where the evidence shows the existence of an assembled, established, well-managed, efficient and productive plant, the Supreme Court will approve an allowance for going value of at least 10 per cent of the value of the physical properties.

VI. CALCULATION OF DEPRECIATION

The opinion deals a death-blow to the theory of "straight-line" depreciation, which had been urged and argued for in the appellants' brief, and proves beyond question that the Supreme Court will reject large deductions based on assumed depreciations calculated on theoretical and arbitrary bases, in every case where the record contains trustworthy testimony by competent engineers who have made an actual inspection of the properties and estimates, based on their inspection, of the percentage of depreciation. The "straight-line" theory, as you know, is based on the age and the assumed life of a particular article. Thus: It is assumed that a piece of pipe will last fifty years. A particular piece of pipe is twenty years old. Therefore there must be deducted, in evaluating it, 40 per cent of its present value, regardless of its actual condition, and evidence of its actual condition is immaterial. It will certainly be useless, since the Water Company decision, to urge this "straight-line" theory. In the trial court the Water Company had presented two theories for providing for the depreciated condition of the property. One was the testimony of a competent engineer who inspected the property and based his estimate of the percentage of existing depreciation on his inspection and a consideration of the probable future life of the property as indicated by the conditions he found. The other was the testimony of a competent engineer who inspected the property and calculated the amount of money that would be required to restore the property to its condition when first installed. The Supreme Court's opinion does not indicate a preference for either of these two theories. Apparently it approves both; certainly it rejects *in toto* the "straight-line" method.

VII. WHAT PROPERTY IS TO BE VALUED?

Or, phrasing it differently, how far may a commission or court go, in calculating present value, in substituting for the value of the actual plant the value of a different plant which the tribunal assumes would be more efficient or more economical in operation than the actual plant? This question was presented to the Supreme Court in the Water Company case by the testimony of one of defendants' witnesses who contended that a steam plan should be substituted for the lower part of the canal at a saving alleged by the witness to be nearly $1,000,000 in value. The Supreme Court completely rejects this attempted substitution and lays down the rule that what is to be ascertained is "the value of the plant used to give the service and not the estimated cost of a different plant." This is not to say that in every case the court will permit the inclusion, in the valuation, of the property actually being used, no matter how obsolete and uselessly expensive it may be. But the Supreme Court says that "save in exceptional circumstances" it will not enter upon a comparison of the methods of different systems. It is clear, therefore, that in the ordinary case, where a utility is in good faith using a particular plant or a particular kind of machinery, the court will not permit the value of that plant or machinery to be excluded from the valuation by testimony attempting to show that some assumed substituted plant or piece of machinery would do the same work more cheaply.

I hope that I have succeeded, in what I have said, in showing the importance that the Indianapolis Water Company decision by the Supreme Court of the United States is bound to assume in future rate controversies. Practically every rate case involves the question of the method of ascertainment of present value, and the question of the proper allowance for going value. Many rate cases involve the questions of reasonable rate of return, allowance for working capital, allowance for water rights, method of calculation of depreciation and questions involving substitutions. Upon all of these questions the Water Company decision is a clear-cut precedent and it will be followed by every court and commission to which it is cited except those, if any there be, which no longer regard the decisions of the Supreme Court of the United States as the final authority.

ELECTROLYTIC CHLORINATION AT SACRAMENTO FILTRATION PLANT[1]

By Harry N. Jenks[2]

Following two and one-half years' experience in the chlorination of the Sacramento water supply with chlorine made electrolytically at the filtration plant, sufficient operating data have been obtained to present for the consideration of those interested in this special phase of water treatment.

The success attending the adoption of this method of chlorination, from the standpoint of reliability as well as of economy, suggests the possibility of there being a wide field of usefulness for what might be termed "home-made" chlorine, not only in the disinfection of water and sewage, but also in those industrial plants where a bleaching agent is required. Again, attention may be drawn to the possible advantages of home-made chlorine in remote localities, where liquid chlorine cannot be obtained at all on account of transportation restrictions. In general, conditions most favorable to electrolytic chlorine equipment are to be found in the medium sized and larger plants, and especially in those located in the West where chlorine prices are relatively high.

PHYSICAL FEATURES OF ELECTROLYTIC PLANT

Credit is due Charles Gilman Hyde, designer of the Sacramento filtration plant, for perceiving in advance the numerous advantages of electrolytic chlorination that were later realized in practice. Professor Hyde's original installation of plant and equipment has been used practically without modification, with the exception of the chlorine cells themselves, which had been purchased in the East and proved to be of incorrect design. These were in due course abandoned after the plant was enlarged, principally through the construction of six new cells designed at the filtration plant.

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[1] Presented before the California Section meeting, October 29, 1926.

[2] Associate Professor of Sanitary Engineering, Iowa State College, Ames, Iowa; formerly Superintendent, Pumping and Filtration Works, Sacramento, California.

The essential component parts of a complete electrolytic chlorinating plant comprise:

a. Salt storage room
b. Brine saturator
c. Brine filter
d. Brine storage tanks
e. Electrolytic cells and appurtenances
f. Chlorine ejectors and piping
g. Direct current generating apparatus
h. Chlorine control panel board

Salt storage room. At the Sacramento plant, commercial rock salt is stored in a concrete bin in the basement of the head house. Its capacity is roughly 30 tons of salt. For calculation of storage space required, the weight of salt may be taken at 72 pounds per cubic foot.

Brine saturator. The saturator at Sacramento is built in the form of a relatively deep, rectangular, concrete tank, divided by a partition wall into two compartments. One of these serves as a holder for the salt, through which water is allowed to percolate upward from a perforated pipe laid close to the hopper bottom. The other compartment receives the overflow from the first as the brine passes over the top of the partition wall, and serves as a storage tank for the brine prior to filtering. A certain amount of sludge settles to the bottom which may conveniently be removed by flushing through a drain opening, at a time when the tank is empty.

The saturator is capable of dissolving as much as 4000 pounds of salt per twenty-four hours, yielding about 500 gallons of brine of 1.2 specific gravity. The required capacity of a saturator may be computed, according to experience, on the basis of 0.6 gallon for each gallon of brine per twenty-four hours it is desired to furnish.

Brine filter. If a filter on the slow sand principle is used, it will be found that frequent scrapings of the sand must be resorted to if the rate reaches 0.1 gallon per square foot per minute, and occasionally the sand has to be completely replaced. Accordingly, a miniature rapid sand filter is to be recommended, such as the one now in use at the Sacramento plant, which may be operated at the usual rate of 2 gallons per square foot per minute. The filter is provided with three 1¼-inch perforated pipe laterals discharging into the brine pump sump and embedded in a cemented gravel slab on which 18 inches of filter sand rests directly. An occasional washing of this filter keeps the sand in excellent condition. A float-operated valve maintains a constant level on the filter as the brine comes from the saturator.

The brine pump is an all-iron, centrifugal pump, direct-connected to an electric motor. Its operation has been entirely satisfactory and no corrosion has been noted.

Brine storage tanks. The brine storage tanks may be made of any convenient size suited to local conditions of operation, but in general they should be in duplicate to allow brine to settle in one while the other is in use. A storage period of two days should ordinarily be satisfactory.

At the Sacramento plant, each of the two storage tanks has a capacity of 500 gallons, the brine being pumped into them and thence flowing by gravity through the brine manifold pipe feeding the cells. A float-controlled angle valve in a small, lead-lined box maintains the required flow from the tanks into the individual chlorine cells.

Electrolytic cells. The design of the cells is characterized by unusual strength and simplicity, and represents the embodiment of numerous excellent ideas and methods gathered by Charles Lundelius, Chief Coagulant Plant Operator, Sacramento filtration works, through many years' experience in the commercial production of chlorine in eastern manufacturing establishments.

The installation consists of six 600-ampere cells mounted in a row as shown in figure 1. The installation is out-doors, the operation being unaffected by the California weather, and any accidental discharge of chlorine is quickly dissipated in the atmosphere. In colder climates, it would be desirable to place a roof over the cells, the actual amount of protection needed being governed primarily by the necessity of keeping the electrolyte and effluent from freezing. In any case, the external temperature should not be so low as to decrease materially the temperature of the electrolyte inside the cells below 70° to 80°C., which is desirable for good operating efficiency.

It may be noted at this point that the space occupied by the cell units is relatively small, so that a large sized plant may be constructed without providing an undue amount of space. In this respect the plant is on a comparable basis with the standard chlorinator installation where room must be allowed for the machines, the weighing scales, and chlorine cylinder storage.

Cell body. The cell body is made of reinforced concrete, the proportions being 1:1:1 of cement, sand and pea-gravel, respectively.

The main casting is in the shape of a "U" with prolonged base. The form for the cells was in reality a wooden pattern for casting the concrete, the general arrangement of the component parts of the form and method of pouring the concrete being indicated in figure 2. The same wooden form was used for each of the cells in turn. A cell could readily be poured in 2 hours and the form could be removed after 12 hours and used on the succeeding cell.

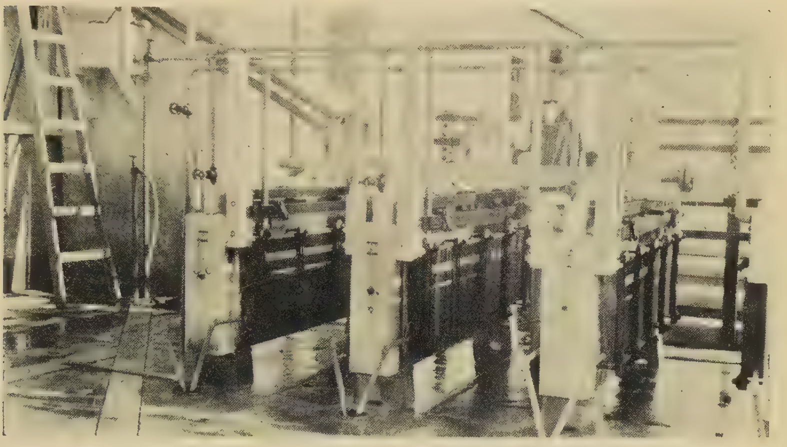

FIG. 1. GENERAL VIEW OF CHLORINE CELL INSTALLATION

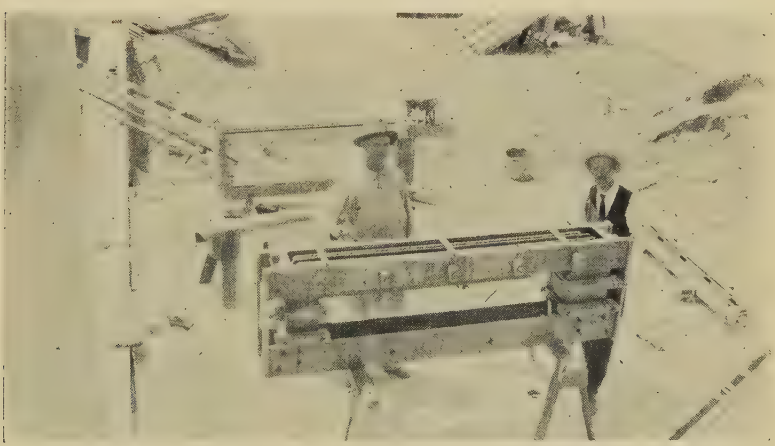

FIG. 2. POURING CELL BODY, SHOWING TYPE OF FORM EMPLOYED

The sides of the cell body were dressed with carborundum bricks to make a plane surface of contact between them and the effluent side pans. A rubber gasket for this purpose or else several thicknesses of asbestos paper glued on around the perimeter of the pan, has been found satisfactory.

The top side pieces of the cell are cemented in after the U-body has set. Spacer blocks serve as compression members to take the thrust of cinching up the bolts passing through the side pieces and serving as anchorages for the steel straps fastening the effluent boxes against the sides of the cell.

The interior of each cell is free from all obstructions, thus permitting the ready insertion and withdrawal of the carbon anode plates. These are supported on the bottom of the cell and the posts extend upward through the cell cover which is made in sections and sealed in place by means of a coal-tar and china-clay putty. Or else a battery-sealing compound in suitable for this purpose. A view of the various features of the cell body just enumerated is shown in figure 3.

It should be noted that the negative bus bar is attached directly to the cathode plate with ample cross-sectional area of metal to transfer the current without loss. All electrical connections are external to the cell, making them accessible, and free from attack by the chlorine.

Electrodes. The carbon anodes are built-up members, consisting of four plates each attached to a square, vertical post, into which is screwed a round carbon rod extending through the cell top and forming the connection with the positive bus bar. The plates are secured to the post by tapered carbon pins driven to a snug fit and assuring an intimate contact between the surfaces of the plates and the post. The general design of the cell is such that electrolysis of the electrodes is greatly retarded. A view of the anode assembly is shown in figure 4.

The carbons were obtained from the Acheson Graphite Company, Niagara Falls, N. Y. The graphitized carbon product manufactured by this company is made especially for electrolytic cells and is of a uniformly high quality.

The cathode plates are secured to the cast iron effluent pans by machine screws and are flat, thus premitting the asbestos diaphragm to be easily laid across the plate and secured thereto. The method of mounting the cathode plates permits quick renewal of the diaphragms, a design feature that is in most instances very poorly at-

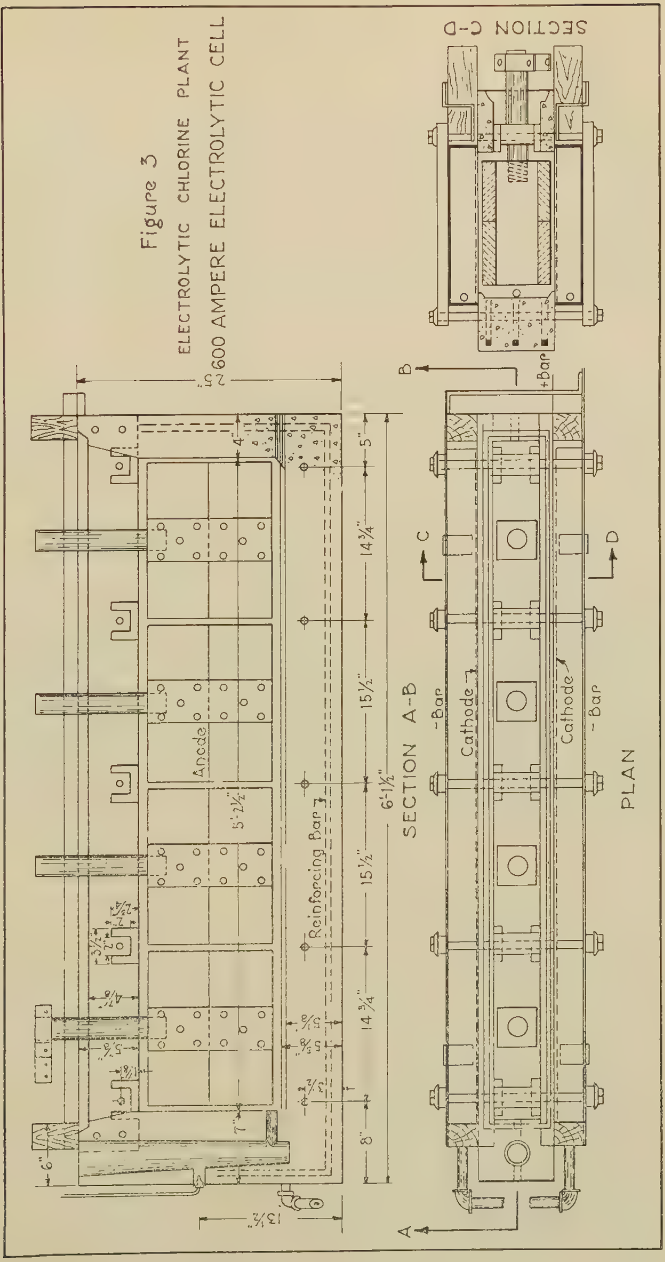
Figure 3
ELECTROLYTIC CHLORINE PLANT
600 AMPERE ELECTROLYTIC CELL
SECTION C-D
SECTION A-B
PLAN
Anode
Reinforcing Bar
Cathode
Cathode
-Bar
-Bar
+Bar
A
B
C
D
25"
4"
5"
14¾"
15½"
15½"
14¾"
6'-1½"
5'-2½"
8"
7"
6"
13½"
5⅝"
5⅝"
2½"
3½"
2"
2¼"
4⅞"
5⅞"

Fig. 3

tended to. No disturbance of any other parts of the cell is occasioned by the removal of the diaphragm, and, conversely, the paper may be replaced without any danger of tearing or sagging.

The cathode plates were furnished by the Hendrick Manufacturing Company, Carbondale, Pa., makers of perforated metals. The specifications called for: Screen plates, No. 16 U. S. gage steel, with $\frac{3}{16}$ by 1 inch slots in straight lines, $\frac{3}{16}$ inch side bar and $\frac{1}{8}$ inch end bar.

These plates were cut to dimensions, with margins and holes drilled for fastening to the effluent boxes. The manufacturers produce a grade of steel plate well suited to the requirements of electrolytic cell design.

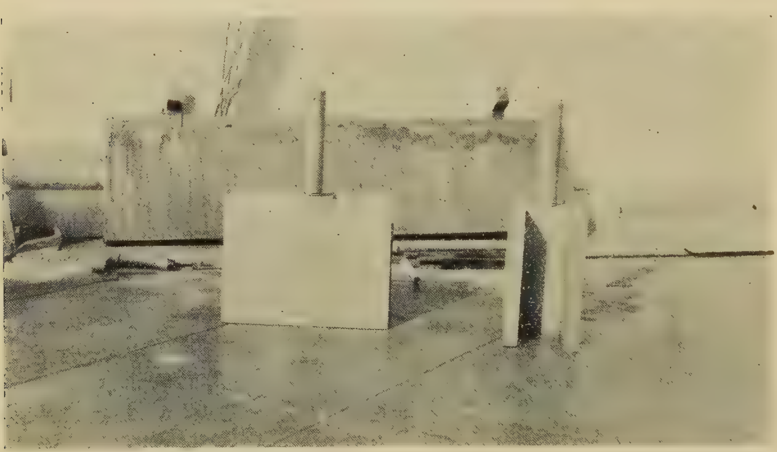

FIG. 4. VIEW OF ANODE ASSEMBLY AND CATHODE PLATE (BACKGROUND)

The asbestos paper used for diaphragms is obtainable from the Johns-Manville Company. It is a special, long fiber asbestos paper of 12 pounds per 100 square feet weight, the thickness being approximately 0.025 inch. This paper is placed, doubled, over the perforated cathode plates. It gives excellent service, the percolation being satisfactory up to the time the paper needs changing on account of lowered current efficiency due to excessive caustic soda concentration in the effluent.

Chlorine manifold and ejectors. As will be noted from the photograph in figure 1, showing a general view of the chlorine cells, the chlorine manifold is made of chemical lead pipe, with lead jumper pieces to allow the gas from any of the cells to enter either the raw water or filtered water discharge line. The cups on the risers from the cells and on the T-connections with the header pipes, contain water seals.

The chlorine manifold piping entails considerable lead-burning if made according to the Sacramento design. In certain instances, either hard rubber or stoneware piping might prove to be more feasible and economical.

The gas is removed from the cells by an ejector on each of the two dosing lines provided. Experience with chemical lead-lined ejectors proved the lead to be subject to excessive corrosion, due, it is presumed, to the combined action of the chlorine and the ejector water, the latter containing considerable carbon dioxide and dissolved oxygen. In replacing the orignial lead-lined ejectors, it was found that an ejector of cast iron throughout, withstands all chemical and mechanical deterioration in a very satisfactory manner. The machine work in making the cast iron ejector was done in the plant machine shop. Hard rubber and stoneware ejectors are equally durable, but are more expensive.

Labor of assembly. The labor expense of constructing one 600-ampere cell having a capacity of 38 pounds of chlorine per twenty-four hours should be very closely as follows:

Machinist	3 days @ $8.00	$24.00
Electrician	3 days @ $10.00	30.00
Pipe-fitter	2 days @ $8.00	16.00
Helper	2 days @ $6.00	12.00
		$92.00

For a larger plant, the actual labor item per cell would be correspondingly reduced.

It is assumed that the work would be done under the direction of a competent designer, whose time should be charged against the job, in whole or in part, according to circumstances.

Direct-current generating apparatus. The original equipment comprised duplicate 300-ampere motor-generator sets. When the chlorine plant was enlarged, a new 600-ampere set was installed. All three units were furnished by the Westinghouse Electric and Manufacturing Company. In connection with the 600-ampere apparatus, the specifications called for a 25 h.p., 3-phase, 60-cycle, 220-volt, squirrel cage induction motor of 40 degrees rating, operating at 1160 r.p.m., direct-connected by flexible coupling to, and mounted on a common cast iron bed plate with, one 600 ampere, 10 to 25-volt, 1160 r.p.m., direct-current generator of not less than 15 kw. capacity

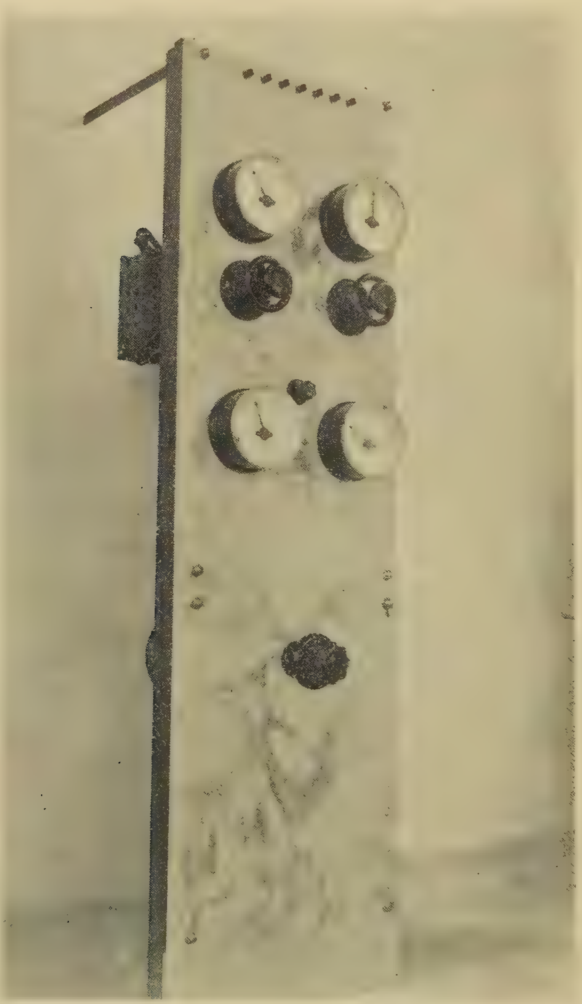

FIG. 5. ELECTRIC CONTROL PANEL BOARD FOR REGULATING CHLORINE DOSE

and capable of delivering full 600 amperes at any voltage from 10 to 25 volts inclusive

Chlorine control panel board. The control equipment for regulating the chlorine dose is located in the filter gallery, as shown in figure 5.

In the immediate vicinity of this control board is another panel upon which the master rate-of-filtration gage is mounted. The filter operator upon reading this gage, consults a chart which gives him the number of amperes at which to operate the cells in order to produce the quantity of chlorine required by the given dose and the amount of water to be treated.

It is the practice to adjust the amperage to the water consumption each half-hour. For any given setting, the current remains constant without any need for adjustment. Signal lights correspondingly to each of the six cells are mounted in a row near the top of the panel and enable the operator to observe from any part of the filter gallery whether the required number of cells is in service. Recently, a siren was installed to give immediate warning whenever a power interruption occurs.

GENERAL CONSIDERATIONS RELATING TO OPERATION

Dependability of operation. Among the chief requirements of a plant of this character is the uninterrupted functioning of the chlorine cells. Experience shows that if the cell installation is divided into a sufficient number of units with at least one cell in reserve, and with proper operation, no failure in chlorine dose need be feared on account of the breakdown of the cells themselves. The probability of the entire plant going out of commission at once is very remote. Evidently only the matter of the need for occasionally stopping the motor-generator set for cleaning or repairs, if but one set is used, and of the failure of power even if duplicate sets are installed, gives rise to the question of the advisability or necessity of providing standby liquid chlorine equipment.

Local conditions affecting the problem of treatment of the water supply or sewage disposal plant effluent will govern in the matter of standby apparatus. Assuming that the highest degree of certainty of uninterrupted service is essential, the question of what type of duplicate equipment shall be installed may be considered from the standpoint of the economics of the situation.

At Sacramento, the motor-generator apparatus is in duplicate, not only insuring reliability, but also great flexibility of operation. The plant has also a standby standard chlorinating apparatus which may be used during prolonged power interruptions or if for any reason the entire cell installation has to be shut down for repairs. Neither of these contingencies has so far occurred.

If liquid chlorine is available, a standby chlorinator may prove to be more economical than a duplicate motor-generator set. In that case a certain number of chlorine cylinders should be purchased outright to avoid storage charges on the emergency reserve supply of chlorine kept at the plant.

On the other hand, if electric power interruptions can be practically eliminated, it would appear better to install duplicate d.c. generator equipment and dispense with the use of liquid chlorine entirely. If there is a large seasonal or even daily fluctuation in the amount of chlorine required, resulting in a widely varying load on the d.c. generator, the economy of using smaller generator sets should be investigated in connection with the selection of duplicate apparatus. Thus on a 600-ampere circuit, the standby equipment might advantageously consist of two 300-ampere motor-generator sets, arranged to run either separately or in parallel.

Practical efficiency of d.c. generation. A recent study of the over-all efficiency of the motor-generator sets showed clearly that they should be operated as nearly up to full d.c. load as possible. Otherwise the current consumption for power on the a.c. side will considerably exceed the useful current producing electrolysis.

An interesting fact also demonstrated by these tests is that, for a given per cent of full load on the d.c. circuit, higher efficiencies are attained throughout the normal range of operation when a greater number of cells are in the circuit. That is, the efficiency in general is increased when the total electrical input into the cells is composed of less amperes at a higher voltage. The practical application of this principle is to operate, when a choice exists, say two cells at 300 amperes rather than one cell at 600 amperes. In either case the amount of chlorine produced is the same. This saving in power, however, may be more than offset by the resulting increased use of salt per pound of chlorine evolved, as will be noted in a succeeding paragraph.

The results of the tests just described are embodied in the form of efficiency curves in figure 6, in which the per cent efficiency is plotted against per cent of full load. The per cent efficiency at the given load is the ratio of the direct-current output to the alternating-current input. It will be observed that the highest efficiency for the 600-ampere set was 75 per cent at 70 per cent full d.c. load; while for the 300-ampere set, the highest efficiency was 70 per cent at full load. In both cases 5 cells were in the circuit.

Utilization of Electrolyte. The brine consumption, which is a measure of the amount of salt used, varies considerably per pound of chlorine produced, on account of the impracticability of operating all the cells at full capacity continuously. When a cell is not working to capacity, the brine percolates through the diaphragms at the full rate just the same, and is wasted to the extent that it has not been electrolyzed, in its passage through the cell.

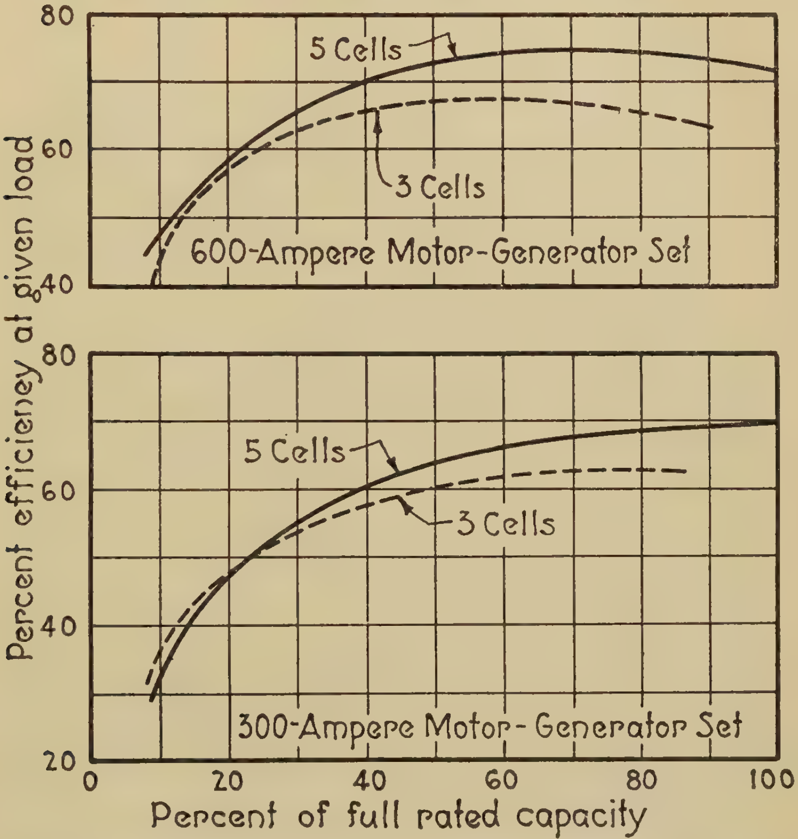

FIG. 6. EFFICIENCY OF MOTOR-GENERATOR SETS IN RELATION TO DIRECT CURRENT LOADING

In the operation of electrolytic cells, it is not practicable to obtain much more than a 50 per cent decomposition efficiency of the brine. At this efficiency the minimum salt requirement is approximately 3.33

pounds per pound of chlorine generated. Under actual operating conditions, involving a variable load, sufficient brine goes to waste to increase the salt consumption as much as 50 per cent. At Sacramento, during the present year, the salt consumption averaged 4.60 pounds per pound of chlorine, or 38 per cent above normal. Except in special cases, it would not be economical to recover the excess brine passing through the cells.

Sustained cell efficiency. The merits of any particular design of electrolytic cell are to be judged by the efficiency that is attained in practice, and the use of correct principles is reflected in the dependability, economy and convenience of operation. Of the three customary tests involving the use of current, the power requirements, and the decomposition of the brine, the basic consideration is that of the current efficiency, especially in the chlorination of public water supplies. That this is so is evident from the fact that the actual weight of chlorine delivered by the cells for any given current in amperes is based on the tacit assumption that the cells are operating at 92 per cent current efficiency or slightly higher. Although the true current efficiency as such must be tested from time to time as indicated in the next paragraph, yet it may safely be assumed that the efficiency will remain close to the required amount if the condition of the cells as a whole is normal. Such a condition is reflected in a well sustained electrical efficiency of the cells as revealed by testing the voltage requirements of the installation.

This last-named feature of operation was investigated after 10 months' continual operation under loads varying from 100 to 600 amperes. The results of this test are given in figure 7. The voltage requirements, being a measure of the resistance of each cell, constitute a good indication of the general conditon of the cells in relation to the necessity of changing diaphragms, cleaning out the sludge accumulations, and renewing the electrodes.

In the diagram, points on each ordinate representing 100 ampere increments in current were obtained from the average of 4 observations on each of 4 cells. It is seen that the typical voltage curve is essentially a straight line; that is, the resistance increases directly with the current. The point at which the line crosses the ordinate of zero current is termed the critical voltage. In this case it is 2.24 volts and is a measure of the counter E.M.F. of the electrolyte.

Referring again to figure 7, a curve has been drawn to show the volts required by the electric circuit only, under actual conditions of plant operation. This includes the effect of all electrical losses between the motor-generator sets and the electrolytic cells, including the connections to the anodes of the latter. From a consideration of both curves of figure 7 the actual electrical load on the d.c. generator can be estimated.

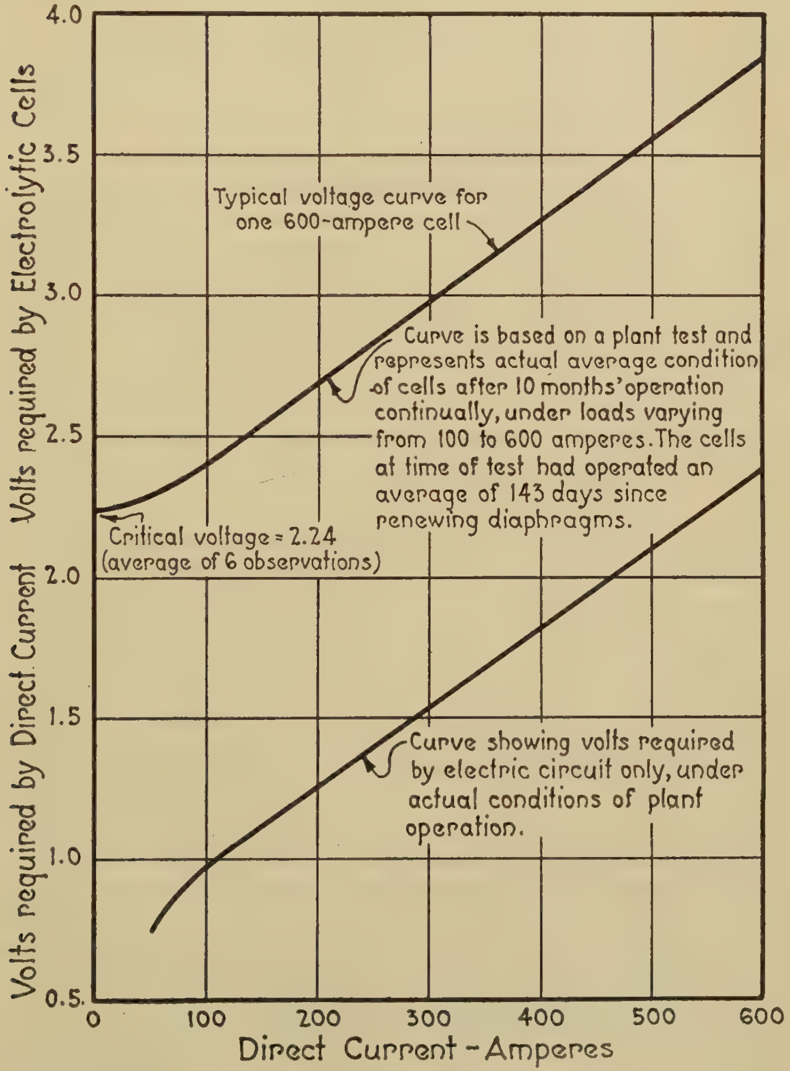

FIG. 7. VOLTAGE REQUIREMENTS OF ELECTROLYTIC CHLORINE CELLS AND VOLTAGE DROP THROUGH D. C. CIRCUIT FROM MOTOR GENERATOR SET

Regulation of chlorine dose. As far as the filter operator's work is concerned, the amount of chlorine fed into the water is varied simply by turning a rheostat handwheel mounted on the chlorine control panel board, as shown in figure 5. The reading on the ammeter corresponds with the dose in parts per million and the rate of filtration in million gallons daily. As previously noted, such simple regulation is based on the assumptions that the amount of chlorine generated is directly proportional to the current passing through the cells, and that the current efficiency remains substantially constant.

The first assumption is based on an acceptance of Faraday's first law of electrolysis a statement of which may be found in any standard work on the subject. This law states in effect that the mass of a substance liberated at an electrode is proportional to the current and the time. In other words, the amount is dependent upon the total quantity of electricity that passes through the electrolyte. Applying this law to the present case, the weight in grams of chlorine liberated from the brine equals a constant times the coulombs of electricity supplied (=amperes per second). The constant is termed the electrochemical equivalent, which for chlorine has been determined as 0.0003675. Accordingly one ampere flowing for one second (=one coulomb) will liberate 0.0003675 gram of chlorine. Making the necessary computations to convert this value into terms of pounds of chlorine per 24 hours, it is found that 600 amperes of current will produce 41.9 pounds of chlorine per 24 hours. In practice, however, this amount is reduced to 38.5 pounds per day, under the assumption that the cells will operate at an average current efficiency of 92 per cent.

This second assumption is verified by actual test from time to time. The efficiency of a cell immediately after changing diaphragms will reach 95 to 97 per cent. Experience shows that thereafter the current efficiency will not fall below 92 per cent during the useful life of the diaphragms, as determined by the percolation and the strength of caustic soda in the effluent. Usually there should be no serious objection to a tolerance of 4 per cent in the chlorine dose, occasioned by the slightly variable efficiency of the cells. At Sacramento, dosing charts are prepared on the basis of 92 per cent current efficiency, so that any deviation is on the side of safety.

In practice, the current efficiency is determined by comparing the amount of sodium hydroxide appearing in the effluent with that which the current passing through the cell at the time of the tes should theoretically produce. From the efficiency so found, the actual amount of chlorine generated may be checked by computation, since the formation of caustic soda and the gas is always on a strictly equivalent basis. The efficiency test should be made at least once a week, and can readily be included in the routine laboratory control of the water or sewage treatment plant. The test is quite simple and reliable, as further noted in the discussion of this paper by Mr. Lundelius.

ELECTROLYTIC CHLORINE COST DATA

Cost of construction of plant. A detailed analysis of the cost of the electrolytic chlorine plant and appurtenances installed at the Sacramento filtration plant is given in table 1. For convenience of reference, the items are grouped under four main headings with corresponding sub-total costs. Except for some of the original equipment installed under contract, the cost figures in general represent closely the actual known expenditures for the various items. It is seen that the total investment is $8171, resulting in a cost of $35.80 per pound of chlorine capacity with duplicate motor-generator sets, and a corresponding cost of $27.10, omitting duplicate d.c. current equipment.

Depreciation allowances. According to experience so far gained through the operation of the plant at Sacramento during the past year it appears that the depreciation of equipment shown in table 2 should be on the side of safety:

Annual fixed charges. Applying the factors for depreciation as given in table 2, to the corresponding initial costs of the component parts of the plant, the following total depreciation charges are obtained, to which are added the interest charges on the investment in determining the total annual capital expense, as set forth in table 3.

In connection with the unit cost per pound of chlorine resulting from the capital investment, it is obvious that the value of 1.64 cents cannot be attained in practice, due to the fact that the plant will not be operated up to its full capacity continuously. The economic plant size in relation to the variations in chlorine demand therefore requires a special study in each instance.

Operating costs. The costs of operation may be grouped into three general classifications:

a. Electric current
b. Salt
c. Supervision

TABLE 1

Analysis of cost of electrolytic chlorine plant installation with 228 pounds per 24 hours rated plant capacity

1. *Brine equipment:*		
Salt storage room	$300.00	
Brine saturator and equipment	300.00	
Brine filter and pump sump	150.00	
Pumping unit, storage tanks and appurtenances	550.00	
Brine lines and miscellaneous piping	200.00	$1,500.00
2. *Electrical equipment:*		
2 600-amp. 10–25 volt. d.c. motor-generator sets installed complete	$4,000.00	
Electric wiring and control equipment	800.00	4,800.00
3. *Chlorine lines:*		
Manifold piping	$200.00	
2 Chlorine ejectors	75.00	275.00
		$6,575.00
4. *Electrolytic chlorine cells:*		
Form for cell body	$15.00	
Concrete and steel for body	15.00	
Cell cover	5.00	
4 Anode assemblies @ $13	52.00	
2 Cathode perforated plates @ $3	6.00	
2 C.I. effluent pans at $15	30.00	
2 Asbestos diaphragms	1.00	
Electrical connections	20.00	
Miscellaneous iron work; bolts, etc	25.00	
Supports and painting	5.00	
	$174.00	
Labor of assembling	92.00	
	$266.00	
× 6 cells =		1,596.00
Total cost of electrolytic chlorine plant		$8,171.00
Capital investment per pound of chlorine capacity		$35.80
Ditto, omitting Duplicate Motor-Generator Set		27.10

The electric current paid for is measured on the a.c. side of the motor-generator equipment by a watt-hour meter, which is read at the end of each month. Except for times when the load falls con-

TABLE 2

Schedule of chlorine plant depreciation

ITEM	PROBABLE USEFUL LIFE	STRAIGHT LINE ANNUAL DEPRECIATION
	years	*per cent*
1. Brine equipment	20	5
2. Electrical equipment	25	4
3. Chlorine lines	5	20
4. Electrolytic cells		
a. Cell body	5	20
b. Cell cover	1	100
c. Anode assembly	2	50
d. Cathode plate	1	100
e. Effluent pan	5	20
f. Diaphragm	¼	400
g. Electrical connections	2	50

TABLE 3

Annual fixed charges, electrolytic chlorine plant, Sacramento, California

ITEM	COST	ANNUAL STRAIGHT LINE DEPRECIATION	
		Per cent	Total
1. Brine equipment	$1,500	5	$75.00
2. Electrical equipment	4,800	4	192.00
3. Chlorine lines	275	20	55.00
4. Electrolytic cells	1,596	39.7*	634.00
	$8,171	11.7†	$956.00
Assume interest charges at 5 per cent (0.05 × $8,171)			$408.55
Total annual fixed charges			$1,364.55
Capital cost of chlorine on basis of full plant production, per pound of chlorine‡			$0.0164

* Weighted average depreciation, including labor.

† Weighted average plant depreciation per year for entire plant.

‡ Plant capacity equals 228 pounds chlorine per 24 hours, or 83,220 pounds per year.

siderably below normal and the consequent efficiency of a.c.–d.c transformation is reduced, as previously shown in figure 6, the amount of current required per pound of chlorine is quite uniform, the average being 2.66 kilowatt-hours.

TABLE 4

Summary of actual cost of manufacture of electrolytic chlorine at Sacramento Filtration Plant

ITEM	PER POUND OF CHLORINE	
	cents	
Capital charges*		1.64
Operating cost:		
Electric current	2.30	4.02
Salt	1.72	
Total		5.66

* Based on continuous operation at full plant capacity of 228 pounds chlorine per 24 hours.

TABLE 5

Analysis of cost of chlorination with liquid chlorine in comparison with that of electrolytic chlorination

Liquid chlorine apparatus:	
2 Standard type chlorinators, with appurtenances, installed	$3,200.00
1 Indicating dial chlorine scales	300.00
	$3,500.00
Allowing 10 per cent yearly depreciation and 5 per cent interest on investment, annual capital charges equal	525.00
Liquid chlorine, purchased in 150-pound cylinders at base price of 12.5 cents per pound	

Summary of comparative unit costs per pound of chlorine

	COST PER POUND OF CHLORINE
	cents
Liquid chlorine apparatus, annual fixed charges*	0.63
Liquid chlorine, operating cost	12.50
Total	13.13
Electrolytic chlorine, total cost	5.66
Saving per pound of chlorine by electrolytic method	7.47
Per cent saving over liquid chlorine	57%
Estimated actual annual saving on basis of operation at full plant capacity, equals $0.0747 × 83,220 pounds	$6,220.00

* On basis of 228 × 365 = 83,220 pounds chlorine dosed per year.

Due to the relatively large block of electric energy purchased by the City for the operation of the pumping station, the electrolytic chlorine plant has the benefit of the low unit cost of current of approximately 0.865 cent per kilowatt-hour. Accordingly, the total cost for current becomes 2.30 cents per pound of chlorine produced.

In reference to the salt consumption, it has been found from a study of the actual amount of salt weighed into the chlorine plant, that the average quantity required is 4.60 pounds per pound of chlorine produced. The corresponding total cost for salt therefore becomes 1.72 cents, taking salt at $7.50 per ton delivered into the storage bin.

The supervision of the plant is part of the regular duties of the filter operators. The amount of time required and the skill of the operator is in no essential different from what is needed in the operation of standard chlorinating apparatus. Occasional assistance is required in making repairs and renewals, but this cost has been included in the item of depreciation.

Summarizing the actual outlay for capital charges and for materials and supplies for operation, table 4 is submitted.

A comparison with the cost of a conventional chlorinator installation, using commercial liquid chlorine, is given in table 5. To place the two different types of plant on a comparable basis of reliability of operation, it is assumed that two chlorinators would be installed, one of these corresponding to the duplicate motor-generator set and appurtenances provided in the electrolytic plant.

CONCLUSIONS

A consideration of the foregoing cost analyses shows clearly that, from the standpoint of expense, the advantage of electrolytic chlorination is dependent primarily on there being a substantial margin between the market price of liquid chlorine and the actual cost of production locally at the treatment plant, a condition that prevails in the West. The writer is aware that in the Eastern market, chlorine commands a price of perhaps 5 to 7 cents per pound, so that electrolytic chlorination could not there compete on the score of cost. Accordingly the reasons for its adoption would have to be based on the favor with which other features of this method might be regarded.

There would doubtless be instances where choice of methods would rest largely upon the judgment of the designer as to which constituted the more desirable one from the standpoint of operation.

The writer is not inclined to press the claims of electrolytic chlorination from this point of view any more than those of liquid chlorine application, because from his experience with each method, both independently and jointly, there appears to be as much to say in favor of one as of the other.

Yet at the Sacramento plant, the electrolytic method has greatly reduced the cost of chlorination, and is much preferred in respect to the ease of control of the chlorine dose and the elimination of the handling and weighing of chlorine cylinders.

In conclusion, it is believed that the experience at Sacramento proves in a convincing manner that the manufacture of electrolytic chlorine in conjunction with the operation of a modern water filtration plant, sewage disposal works, or industrial establishment is thoroughly feasible, and may often be of decided economic advantage in effecting a substantial saving in the cost of chlorination, especially on the Pacific Coast.

DISCUSSION

CHARLES LUNDELIUS[3] (by letter): In elaborating somewhat on Professor Jenks' paper on the use of electrolytic chlorine in the treatment of the Sacramento water supply, it may be of interest to review very briefly the historical development of the present type of chlorine cells.

The chlorine of commerce is obtained from sodium chloride (common salt) by means of some electrolytic process. As the electrolysis of brine on a commercial scale is comparatively new, it is often looked upon as something mysterious, to be attempted only by the initiated. As a matter of fact, however, few manufacturing processes are as simple.

The essential requirements of an electrolytic cell include merely a pair of electrodes and the passage of a direct current of electricity between them, in a solution of salt in water. The primary products formed in so simple a cell, however, would immediately enter into secondary reactions, and not be available as desired. The primary products referred to comprise negatively charged chlorine ions and positively charged sodium ions. The former release their negative charges upon coming in contact with the anode and are liberated as free chlorine gas. At the cathode the sodium ions give up their positive charge and immediately react with the water of the electrolyte to form sodium hydroxide (caustic soda), at the same time liberating hydrogen from the water molecule. The aim of the various cell designs has always been that of removing these substances, chlorine, caustic soda and hydrogen, from the zone of electrochemical activity as rapidly as they are formed, thus avoiding the secondary reactions that lower the cell efficiency and are destructive to the cell itself.

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[3] Chief Coagulant Plant Operator, Sacramento Pumping and Filtration Works, Sacramento, Calif.

In an effort to accomplish this result, designers have continually changed the physical arrangement of the cells, until perhaps the greatest advance was made in this respect when, about 1890, Gresheim designed a cell having a porous diaphragm intended to remove the sodium ions as fast as formed. Though it solved this problem, the process could not be carried on continuously; when about one-third of the salt had been decomposed, the cell had to be shut down and the brine renewed. Other types followed in quick succession, so that it is difficult to state who first developed the present type of diaphragm cell.

In general, these cells are made of concrete, comprising a bottom and two ends, roughly forming a "U." Inside of this frame are placed carbon plates forming the anodes. These project above the cell covers and are connected in parallel to the positive bus bar. Against the two open sides are placed a perforated steel plate covered with asbestos paper. The plate forms the cathode while the paper is the diaphragm. When a current is passed through the cell, chlorine is liberated at the anode and is drawn off as fast as formed through a hole in the cover, while the sodium migrates to the cathode. The sodium passes through the diaphragm in the ionic state, but on coming in contact with the cathode plate becomes metallic sodium which reacts with the water of the brine to form NaOH and hydrogen, outside of the portion of the cell containing the electrolyte. Accordingly the caustic is removed in the effluent and the hydrogen escapes to the atmosphere through suitable vents in the effluent pans. As this operation proceeds over a period of two or three months, the asbestos paper becomes clogged by impurities in the brine and needs to be renewed. This is a matter of cell upkeep and is a simple and inexpensive item.

In operation, the cells require no other attention than to see that the brine does not fall below the top of the diaphragm and that a constant suction of about $\frac{1}{8}$-inch of water is maintained, in order to remove the chlorine gas from the cell as fast as it is produced. Occasionally, also, the electrical connections to the carbon posts require cleaning and tightening up.

TABLE 6

Determination of electrolytic chlorine cell efficiencies

Note amount of current in amperes passing through the cell.

Hold current constant at least 15 minutes before taking sample of effluent.

Collect a one-minute sample of the effluent. This amount, multiplied by 60, gives the percolation per hour.

Then draw off 10 cc. of the sample into a suitable flask, dilute with water and titrate with N/1 H_2SO_4. The number of cubic centimeters of sulphuric acid used, multiplied by 0.04 (normal factor for NaOH) gives the amount of NaOH in grams, in the sample titrated. By proportion, determine the weight of NaOH appearing in the effluent during one hour.

Multiply current noted above, by 1.494 (= NaOH in grams produced by one ampere in one hour), to obtain the weight of NaOH that should be produced at 100 per cent current efficiency, during one hour.

The actual amount of NaOH produced divided by the theoretical amount (for 100 per cent efficiency) gives the actual current efficiency at the time of the test.

Example:

Current = 600 amperes × 1.494 = 896.4 grams NaOH per hour.
Percolation = 150 cc. per minute = 9000 cc. per hour.
10 cc. sample required 23.0 cc. N/1 H_2SO_4.

Then 23.0 × 0.04 = 0.92 gram NaOH
Whence amount produced = 0.92 × 9000/10 = 828.0 grams NaOH per hour

Therefore Current Efficiency = 828/896.4 = 92.3 per cent

If the voltage required should be, say, 3.6 volts
Then 2.3/3.6 = 63.9 per cent = Power Efficiency
And 63.9 per cent × 92.3 per cent = 59.0 per cent = Energy Efficiency

If the brine should contain 317.9 grams NaCl per liter (equivalent to 2.64 pounds per gallon @ sp. gr. 1.2)
And the effluent should contain 158.9 grams NaCl per liter
Then 158.9/317.9 = 0.50 or 50 per cent = Decomposition Efficiency

The voltage required when the cell is new is generally between 3.2 and 3.5 volts. This will gradually increase due to increased resistance of the anodes and electrolyte resulting chiefly from secondary reactions and the presence of impurities. The voltage should not be allowed to rise much above 4.0 volts, when the anodes should be examined and, if necessary, renewed in whole or in part.

In a cell of 600–ampere capacity, about 9000 cc. of effluent should percolate through the diaphragm per hour. This will give a caustic strength of between 7 and 8 per cent. In any case, the percentage of caustic should never be allowed to rise above 11 per cent, as the percolation then would necessarily be too low to carry off the sodium ions, which would in turn remain in the electrolyte and cause secondary reactions, forming sodium hypochlorite, chlorate and perchlorate. The cell efficiency is thus reduced as both sodium and chlorine are lost as far as availability for the purposes desired is concerned. The remedy is to renew the diaphragms.

The brine is a salt solution of approximately 25 per cent NaCl, having a specific gravity of 1.2. In commercial installations, the brine should be purified to eliminate Na_2SO_4 and Na_2CO_3, and it is also customary to have it either slightly acid or alkaline. How much of this treatment is warranted depends upon circumstances. In general, the purer the brine is, the longer the diaphragms will last. In practice, in installations of the sort under consideration, it is sufficient simply to pass the brine through a sand filter. Finally, as the resistance of an electrolyte decreases with the temperature, it is well to keep the temperature high, or from 70° to 80°C.

If it is desired to operate the cells at the highest efficiency, as in commercial installations, daily tests must be made of the composition of the effluent, and the loss of voltage across each cell should be observed. These tests are quite simple, in practice the voltage being read and recorded each time the chlorine dose is regulated; and the effluent is titrated by the chemist at pre-determined intervals. In connection with the treatment of water with the chlorine produced, the test for caustic in the effluent may properly be made once a week, and, as Professor Jenks states in his paper, may conveniently be made a part of the routine laboratory control of the water purification works.

As already stated, the cell efficiency may be determined by measuring the amount of caustic soda contained in the cell effluent, from which the actual amount of chlorine being produced at the time may be accurately computed, on the basis of their chemical combining weights. In the determination of electrolytic cell efficiencies, table 6 is given as illustrative of the general method and the laboratory procedure to be followed.

THE DENVER FILTER PLANT

By James H. Fuertes[1]

The new 64-million gallon Marston Lake Water Purification Plant put into operation in August, 1925, at Denver, Colorado has many novel and interesting features. The process is that of rapid filtration preceded by screening, aeration, coagulation and accompanied by sterilization.

The works consist of an intake, screening plant, aerators, mixing chambers, coagulation basin, rapid filters, clear water reservoir and a boiler pump and head house containing the mechanical equipment, heating boilers, coagulant storage, storage facilities for wash water, high pressure water and air. The water treated is drawn from Marston Lake which in itself is fed largely from the South Platte River.

CHARACTER OF WATER

The results from the filtration of Marston Lake water are very good, notwithstanding the fact that the Denver water is difficult to purify. It is somewhat turbid and contaminated, but its worst feature is that it contains an extremely high content of microorganisms of the worst variety. These organisms are short lived and their decomposition gives rise to tastes and odors extreme at some seasons of the year. A further difficulty is that some of the organisms in their live state are free swimming and have a remarkable tendency to penetrate and pass filters of the ordinary rapid type. They are so numerous that they would completely stop up slow filters.

SPECIAL FEATURES

The filter plant is one especially designed for this particular water and differs from the ordinary rapid filter plant in many particulars. Among the novel features are:

The low head losses used through the filters as well as the basins and conduits to make possible the use of the available head for adequate aeration without pumping. The filters work under a maximum head loss of 3½ feet instead of the customary 10 feet.

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[1] Consulting Engineer, New York, N. Y.

The use of coarse grained filters (0.7 mm. effective size, and uniformity coefficient of 1.8), with a 5-foot depth of filtering material.

The equipment of 5 m.g.d. filter units for operation by hand, rather than with rate controllers.

The use of large and extremely sensitive inspection wells for the observation of the filter effluents from each filter.

The novel gauges.

The use of closely spaced solid stream nozzles.

The use of fine screening preliminary to coagulation.

INTAKE AND FINE SCREENS

An intake of 90-inch concrete pipe extends into the lake 1300 feet to a depth of 60 feet and is equipped at the outer end with a removable conical brass screen with ½-inch mesh. Double control gates are provided at the shore end. At this point also is a screen house containing forty and sixty mesh copper screens mounted on three motor driven belts, operating in a pit 57 feet deep. These screens are cleaned by sprays of water under 100 pounds pressure. The purpose of this installation is to remove the larger of the micro-organisms as well as any fish or debris which pass the coarse screen at the outer end of the intake. The screens take a part of the load from the filters.

AERATORS, MIXING CHAMBERS, AND COAGULATION BASIN

The water leaving the screens passes, by means of a 90-inch concrete pipe, through a Venturi meter to the aerators over the mixing chambers. The water enters the fifty independently valved, 10-inch cast iron lateral pipes and flows to six hundred bronze nozzles, spaced 3 feet center to center. The nozzles are of a type which throw the water up in a solid, straight stream. This method conserves of space, gains maximum height of stream and produces a large amount of entrapped air.

The water falls directly into the mixing chambers, at which point it receives the coagulants, the dosage varying from 0.2 to 1.0 grain per gallon of alum and 0.0 to 0.5 grain per gallon of lime. Although the raw water has a bicarbonate alkalinity of 100 p.p.m. and over, it is found that a small dosage of hydrated lime improves the coagulation. After passing through the five mixing chambers, having a total retention period of twenty minutes, and the coagulation basin,

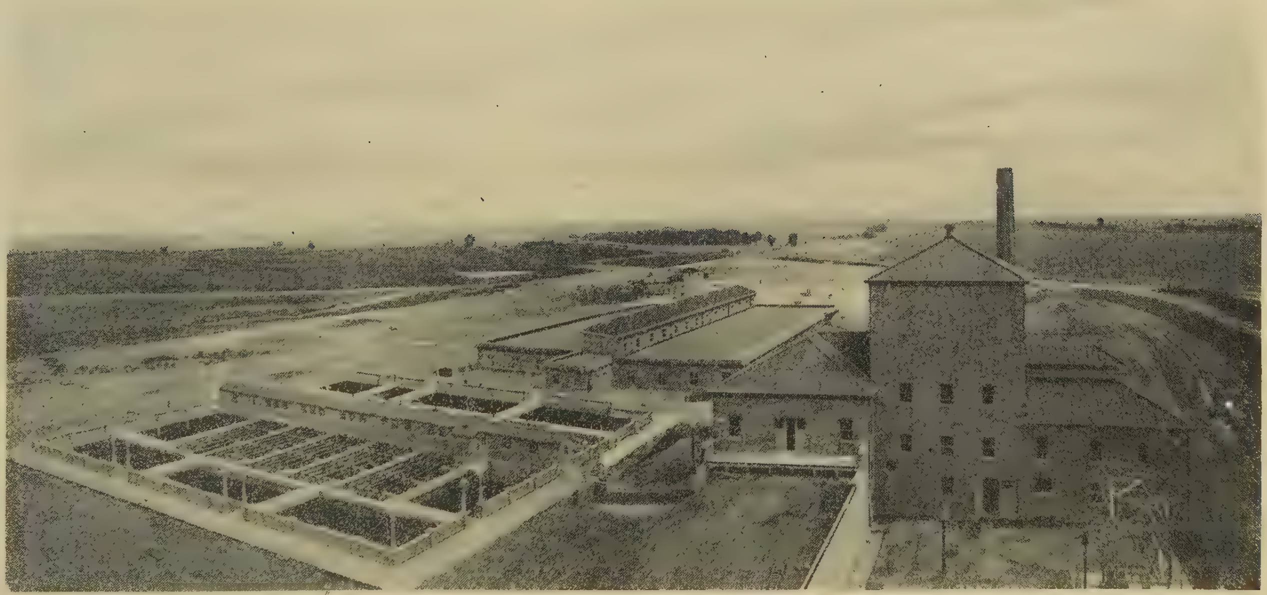

Fig. 1. General View of Marston Lake Filter Plant Looking Northeast towards Denver

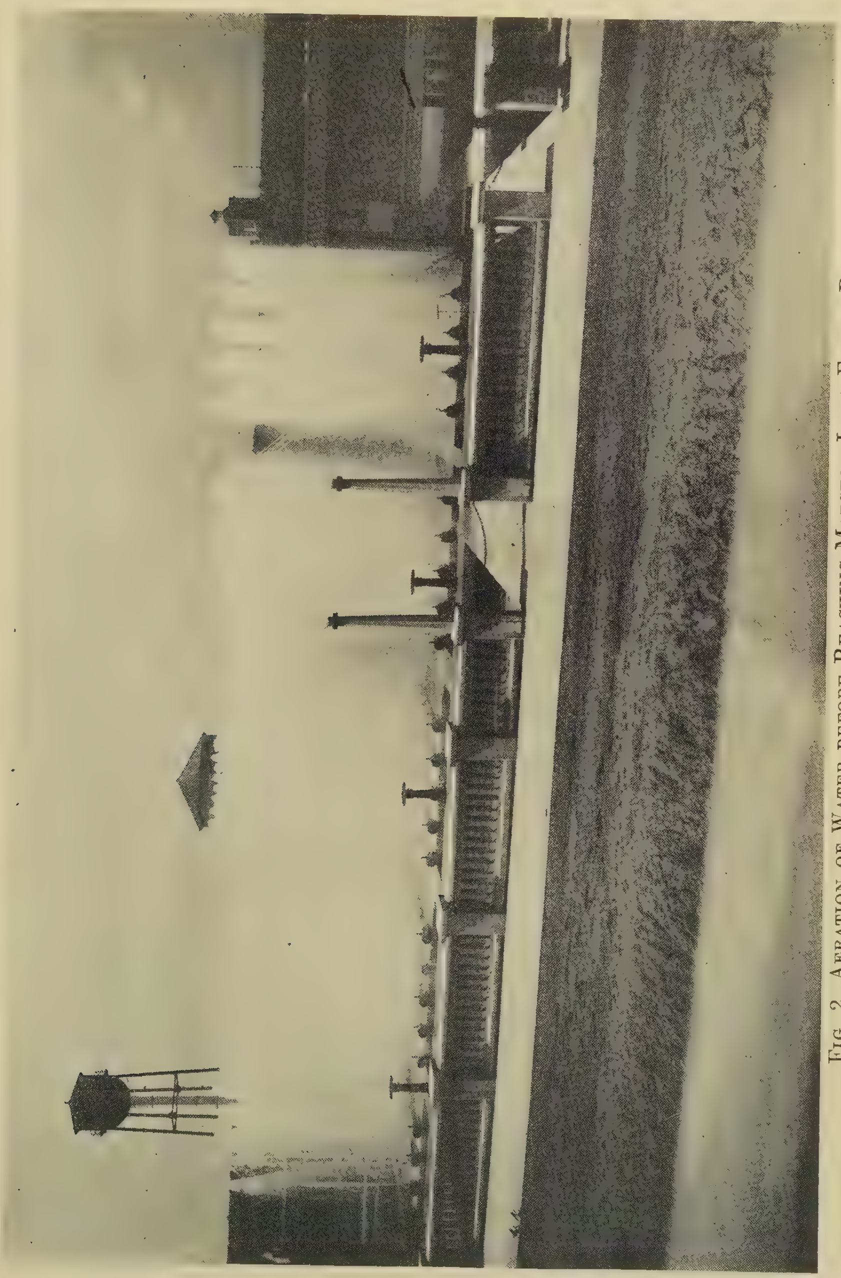

Fig. 2. Aeration of Water before Reaching Marston Lake Filter Plant

the water flows directly to the filters, having had a total coagulation period of one hour.

In order to give an artistic design and at the same time provide an exposed water surface into which the spray from the nozzles will fall when blown by the wind, the coagulation basin is built surrounding the mixing chambers, the whole forming one large basin. This basin is provided with walks around and across it, so that the water may be observed during its coagulation.

LOW HEAD LOSS, HIGH RATE FILTERS

The coagulated water enters each filter from a flume at the end away from the central operating floor. All of the other filter connections are made to pipes and flumes in a pipe gallery under the operating floor.

The filtering material is hard anthracite coal, effective size 0.7 mm. and uniformity coefficient 1.8, placed in beds 5 feet deep and supported by 14 inches of gravel, graded in three layers and of a size varying from 0.75 to 0.05 inch. The strainer system is of 3-inch perforated pipes, 8 inches center to center with $\frac{3}{8}$-inch holes in their bottoms, 4 inches center to center, the same pipes being arranged to give a uniform distribution of both air and water wash. Reinforced concrete wash water gutters are used. Extremely sensitive inspection wells 7 feet deep are provided on the individual filter effluents. These have white glass bottoms which reflect light thrown from high-powered incandescent lamps above. The wells have transparent plate-glass covers.

The filters operate under a maximum head loss of $3\frac{1}{2}$ feet. They are controlled by hand without rate controllers, the water always being under close observance. The filters have both air and water wash, the latter varied in rate according to the character of the water treated, the usual operating range being 8 to 15 inches per minute.

All filters have rate of flow, loss of head and rate of wash gauges. The latter are actuated by loss of head of wash water and were calibrated in the field. The dials will be checked at intervals of time and, if necessary, corrected.

The filters are equipped with hydraulic valves, controlled from operating stands. The valves have attached directly to them position indicators, all visible from the operating stands.

The filter room is also provided with distant indicating gauges showing the level of the water in the clear water reservoir and the

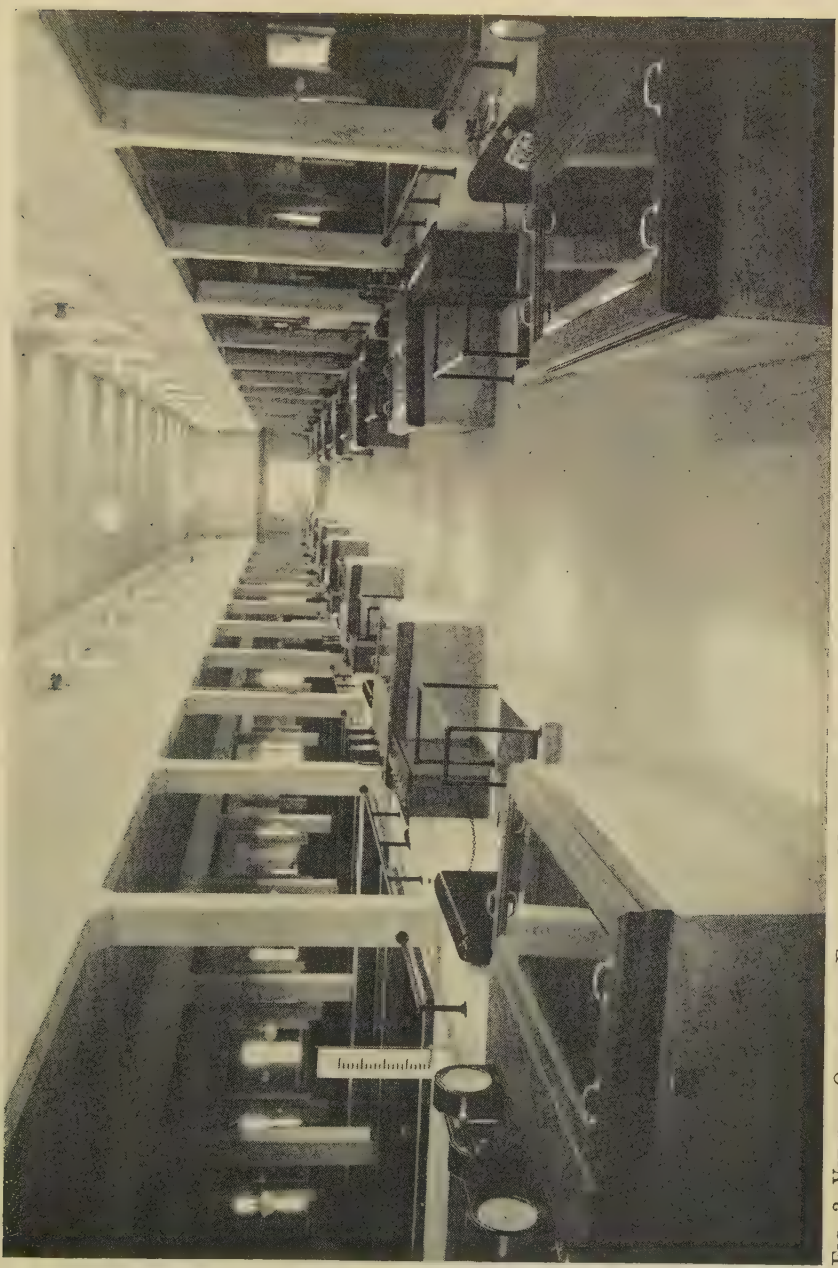

FIG. 3. VIEW OF OPERATING FLOOR OF MARSTON LAKE FILTER PLANT SHOWING THE FOURTEEN 5-MILLION-GALLON UNITS

rate at which it is being drawn from the reservoir to the city. The rate of flow to the aerators and the water level in the coagulation basin is indicated at the head house from which point the inflowing water is controlled.

THE FILTERED WATER RESERVOIR

The reservoir has a capacity, when full, of 10 million gallons. This is covered by a flat slab reinforced concrete roof.

BOILER PUMP AND HEAD HOUSE

In this building is provided a storage room for two months' use of coagulants, this being above the room in which the dry feed machines are installed. Chemicals are stored on a flat floor. The tops of the hoppers of the dry feed machines are under hatchways in this floor and these hoppers are loaded once each shift when required. The mechanical equipment is in the same building and consists of:

Three 3500 g.p.m., 75-foot head, wash water pumps which pump water to a 160,000-gallon reinforced concrete wash water tank overhead.
One 500 g.p.m. 120-pounds pressure pump.
Two 250 g.p.m. 120 pounds pressure pump.
Two 300 cubic feet per minute 100 pounds air compressors.
Two heating boilers.

All mechanical equipment is electric driven, the power being brought in by two independent 13,000 volt lines and stepped down at an outdoor transformer sub-station at the plant.

GENERAL

Reinforced concrete is used as the structural material throughout. The housing is in buildings of light tan or brown color brick with red tile roofs. Construction work was started in June, 1924, and completed in July, 1925.

COSTS OF CONSTRUCTION

The entire plant of 64 m.g.d. capacity was built with an intake for $2,000,000, all costs except land, included. The cost of the filter plant alone amounted to $26,000 per million gallons daily.

As far as I know, this is one of the least expensive water purification plants for the treatment of a water as difficult to purify. This is notwithstanding the fact that certain local conditions of construction made the work cost ten per cent more than might usually be expected. The usual cost for rapid filter plants at present prices, all costs included, is $30,000 to $40,000 per million gallons. Slow sand filter installations, operating at the usual rates, cost twice as much.

OPERATING COSTS

The costs of purifying water are the lowest of any plant that I know about, treating water under comparable conditions. The operation cost is $5.75 per million gallons. The total cost of purifying water, including interest, depreciation and all charges, is $9.75 per million gallons. This is based on the full rated capacity of the plant. Comparisons of operating costs with other plants are apt to be misleading, since costs vary so greatly with the character of the water treated, the size of the plant, local price conditions, and the wisdom and economy of administration. Some general comparisons of value may be made, however. I may say that the usual costs of purifying water under conditions at all comparable with those at Denver range from $11 to $18 per million gallons, all costs included, based on valuations at present prices, and with charges figured in a manner similar to that used for the Denver plant. I know of only one plant showing a cost as low as that at Denver. This is the plant at Montreal, Quebec, which was built after the findings of the double filtration plant at Steelton, Pennsylvania, mentioned herein.

Three particular items contribute to the economy at Denver:

1. Low labor cost. The plant is operated at the full rate by labor (total on payroll) of 2.0 man hours per million gallons.
2. Low doses of coagulants are used, the average for 1926 being: alum, 0.64 grain per gallon; lime, 0.27 grain per gallon.
3. Interest and depreciation charges based on the low installation cost given above, result in low fixed charges.

ADVANTAGE OF DENVER TYPE PLANT FOR USE IN CONJUNCTION WITH EXISTING SLOW FILTER

There are many existing slow filter plants which need increased capacity or will need it in the near future. The development of the rapid filters of the Denver type opens the way for the enlargement of these plants at a small installation cost and provides a means for the purification of the water at a cost lower than can be obtained in any other way. Their use as pre-filters enables these filters to operate at rates of from 12 to 15 as against the 2 to 6 million gallons per acre per day now used. The purification effected by the double plant is of the highest character and offers a security furnished by no other method.

Reason for low construction cost of high rate double plant

The rapid filters work at a 50 per cent higher rate than is customary in rapid filter plant practice, or that usually used in prefilters. This means 50 per cent less filter area. The preliminary filters of the type in question are simpler of operation and require less regulating and control apparatus than the usual mechanical filters. The slow filters working at rates three to five times as great as those usually used result in a small filter area and a low installation cost. Where existing slow filters are now in good condition, they can be adapted for use at high rates with a double plant by minor changes of piping and regulating apparatus and by a re-sizing of the sand. As compared to an abandonment of present slow filters, or a continuance of their operation as at present, supplemented by filters of another or of the same type, the double plant as above considered gives by far the lowest installation cost.

Reason for low operating cost

First, the double plant of the type considered will use extremely low doses of alum. An example of this economy is offered by the comparison of the Harrisburg and Steelton plants in Pennsylvania, both treating Susquehanna River water. The Steelton plant in addition gets Harrisburg's sewage. The plant at Harrisburg is a rapid filter plant of a type quite similar to many now in use. The Steelton plant is a double filter plant of the type under discussion here. The Steelton plant operates on an average dose of 0.18 grain per gallon of alum, whereas Harrisburg uses 0.5 grain per gallon. Seven tenths to one grain is perhaps more usually experienced for similar waters. The saving here is one dollar per million gallons. Secondly, because of the low installation cost, the fixed charges will be correspondingly low.

I have recently made estimates for the enlargement of two rapid sand filter plants by the addition of preliminary high rate scrubbers and the increasing of the rate on the slow filters. They have exemplified to a marked degree the economy of the method. In preparation for one of these changes for a plant enlarged to 50 m.g.d.

capacity test filters have been operated for almost a year and estimate designs prepared. It was found that the double filter plant would make a saving of several hundred thousand dollars in first cost over any other type of enlargement, and would net a saving in costs of purifying the water of $15,000 per year. The other plant is a similar case, though slightly smaller, and it was found that the saving by the use of double filters of the above mentioned type would be over $100,000 in construction cost and between $10,000 and $20,000 per year in operating costs. In both cases it was found that the water would be purified by the double plant at a cost considerably under ten dollars per million gallons delivered, all costs included, with complete plant valued at present prices.

The fact that operating costs as low as those contemplated can be actually accomplished has not only been demonstrated by the experimental station at Denver and at Harrisburg (these were actual plants on a small scale), but also by the operation of the 3 m.g.d. plant at Steelton, Pa. This plant has been in operation for nineteen years and, although a small plant, data from it are applicable in the establishment of costs of operation for a larger plant. Furthermore, the 64 m.g. plant recently built at Denver, which has been in operation or a year, further corroborates the figures. This is a rapid plant only, but it is of the same type which is considered in this paper for use as preliminary filters for a double plant.

An added advantage of double filters is in their extreme reliability. One of the greatest weaknesses of any plant for the purification of the public water supply is in the possibility of human failure. If everyone is on the job all the time and if everything is working as it should be, the plant will work all right, but these things do not always happen. Someone forgets and somebody is not there, or some part of the operation or equipment is out of order and, consequently, some water gets by not properly purified. In recent years the application of chlorine has furnished a great safeguard of reliability, but chlorine machines, like other mechanical equipment, are subject to periods of break-down or to being shut off when no one is looking, to save a few dollars.

Too much emphasis cannot be placed upon the necessity of absolute reliability. Double filters offer a reliability which is perhaps furnished by no other means. If for some reason the pre-filters are out of service or do not stop the contamination it is sure to be caught on the final filters and the chlorine offers a further protection which it is well to have.

These facts of reliability are not new ones. They have been appreciated for years and probably more in Europe than in this country. The reason that double filters have not been more used in the past is that they have been more costly to build and operate than other types of purification plants. Now, however, with the fact established, as I believe it has been by the work above mentioned, that double filters can operate at rates so high and doses of coagulants so low that the costs of purifying water are actually below those usually obtained, the double filter plant seems very attractive.

DISCUSSION

Frederick H. Weed:[2] Mr. Fuertes' paper describes a water filtration plant which is strikingly different from the usual practice. For this reason and because of the unusual character of the water treated, the plant is worthy of note by water works' men. The latter part of the paper, which deals with the applicability of filters of the Denver type for use as scrubbers of a double filter plant, and the consideration of the use of high rates on such a plant is in a field which, I believe, will be found new to many men. There are others, however, who have had experiences along this line and it is hoped that this paper will bring out many discussions. There are many cases where the use of high rate double filtration will give better results than either mechanical or slow filters alone, at no greater cost and with a greater certainty of safety. Where there are existing slow sand filters, the opportunity of an economical development by this means is great.

Since the writer carried on certain parts of the work mentioned in Mr. Fuertes' paper, it may be to advantage to set down some of the details not included in his general statements. The work in Denver did much to confirm the earlier results obtained from the double filtration plant at Steelton which was put into operation in 1908 and those of the experimental plant operated at Harrisburg prior to the construction of the rapid filters for that city.

[2] Formerly with James H. Fuertes, Consulting Engineer, New York, N. Y., now with Gannett, Seelye and Fleming, Engrs., Inc., Harrisburg, Pa.

A YEAR'S TEST FOR A DOUBLE FILTRATION PLANT FOR DENVER

In preparation for the enlargement of the old slow filter plant at the foot of the Platte Canyon at Denver, an experimental filter plant was operated for a year to test the effect of high rate double filtration. These tests were made with a small filter plant made for the purpose. This had a maximum capacity of 180,000 gallons per day. This plant showed to a marked degree the applicability of the high rates considered by Mr. Fuertes for use in a double filter plant. The water treated was contaminated and, at times, carried a high turbidity. Judging from the results obtained by this plant, the high rates as considered by Mr. Fuertes are not excessive. The rapid filters operated for days at a time at rates up to 220 m.g. per acre per day, handling water of over 100 p.p.m. turbidity with maximum turbidities up to 600 p.p.m. The average rate over the whole period in which the worst water was treated and covering the wide range of rates tried was 160 m.g. per acre per day. The effluent from these rapid filters which was put on to the slow filters averaged a turbidity of 2 p.p.m., which was completely removed by the slow filters, as far as the usual turbidity tests would indicate. The slow filters operated at an average rate of 18 m.g. per acre per day, which included the wide fluctuation of rates tried. The filters showed a capability of treating this water up to rates of 23 million gallons per acre per day. Furthermore, the slow filters, under these conditions, delivered 500 million gallons of water per acre cleaned. At no time was the effluent of the plant other than first quality for a municipal supply.

Bacterial efficiency of the plant

Bacterial efficiencies were measured without the use of chlorine or any disinfecting agent. The plant showed an average bacterial efficiency at the rates considered safe by Mr. Fuertes (15 m.g.a.d. on slow filters, 175 m.g.a.d. on scrubbers) of 98 per cent. This efficiency is about what might be expected from a slow filter plant alone operated at a rate of approximately 6 m.g.a.d., and is considerably better than that obtained by the usual rapid filter plant, working at 100 to 125 m.g.a.d. which, if I am not mistaken, might show efficiencies without the use of chlorine of from 80 to 90 per cent on waters somewhat similar to that treated at Denver. It is recognized, of course, that a greater bacterial reduction can be secured by an increased dose of alum applied for this particular purpose.

The efficiency of the slow filters alone of this test plant is worthy of note. There have been some cases put on record where the efficiency of slow filters varied inversely as the square of the rate of filtration. With this plant, however, the indication was that the efficiency dropped much less rapidly with the increase of the rate, in fact, more nearly in direct proportion to the increase of rate rather than its square. The average efficiency of the slow filters at 15 m.g.a.d. was 95 per cent.

THE STEELTON FILTERS

Mr. Fuertes mentioned the double filtration plant at Steelton as an example of high rate double filtration. While the matter is under consideration here, it may be well to state that this plant treats the Susquehanna River water which has an average turbidity of 50 p.p.m. throughout the year and a maximum turbidity running for days at a time of 1500 p.p.m. The pollution by sewage and mine wastes is high. This plant operates throughout the year with an average dose of alum of less than 0.2 grain per gallon. The coarse grained scrubbers remove nearly all the turbidity, the final filters taking out the rest and effecting the principal bacterial purification. Notwithstanding the low alum doses, the final filters give long runs and have shown no sub-surface clogging in their nineteen years of operation. The filters deliver approximately 350 million gallons of water per acre cleaned and at times have gone to 500. Throughout one year they delivered 1700 million gallons per acre cleaned. With as little cleaning required as this, it can be readily seen that the costs of the slow filter operation are very low. The rates of filtration at Steelton are not nearly as high as those considered at Denver and Montreal.

MONTREAL FILTERS

In regard to the Montreal filters, mentioned by Mr. Fuertes in his statements about double filtration, it may be said that as far as the writer knows this plant has the largest high rate double filtration plant in operation. It delivers approximately 75 m.g.d. and operates with the rapid filters working at average rates of 175 m.g.a.d. and the slow filters at 11 to 13 m.g.a.d. This plant gives an extremely low cost of purifying the water. Although the water at

Montreal is not as difficult to treat as that of the Susquehanna River at Harrisburg and Steelton, or the Denver water, it may, nevertheless, be of interest to make a comparison of costs. The average turbidity runs about 11 p.p.m. with maximums of 100 or 150 p.p.m. The water is contaminated.

According to the paper by F. E. Field, in the Journal of the New England Water Works Association, Vol. 39, No. 3, the cost of operation for 1924 was $2.50 per million gallons. Probably the total charges based on present valuations and figured on the same basis used by Mr. Fuertes would give a total cost of purifying the water of about $8.50 per m.g. The slow filters give high runs per cleaning of approximately 375 m.g. of water per acre cleaned.

It has been stated that the double filter plant at Montreal was built to protect the slow filters from plankton growths and that, since the growths have not occurred to the extent anticipated, the double filters are not justified. I understand also that in the enlargement which is to be made at Montreal, rapid filters only are to be built. These facts are, however, not a detriment to the citing of Montreal as evidence of the economy of double filter plants, working at high rates, as demonstrated by Mr. Fuertes in his work, since this plant has been in operation for eight years, giving excellent results at extremely low costs. In fact, the Montreal experience may be the most conclusive proof to those who like to see proof on a large scale and who would give some discredit to results obtained by a test filter plant, and would perhaps consider the three million gallon plant at Steelton a small scale demonstration only. Without doubt, if there were any slow filters now working at low rates at Montreal, it would be better to increase their rate with pre-filters rather than build supplementary mechanical filters. The only slow filters they have already operate at the high rates.

ADVANTAGE OF LOW HEAD SCRUBBERS

There are many cases where the low head feature of the scrubbers, as developed by Mr. Fuertes is very valuable. When pumping can be avoided a considerable amount of money is saved. The necessity of pumping the water through a filter plant often increases the cost of purification by 25 per cent.

SUMMARY

The real advantage, as the writer sees it, in the type of double filters as developed by Mr. Fuertes, is that his plant utilizes to the best possible advantage the qualities of both slow and rapid filters. The scrubbers treat the water only to the extent required for the most economical operation of the slow filters, and no more. The amount of coagulation and alum required will vary from nothing, as at Montreal, to some extent, such as used at Steelton, but in all cases will be much less than would be required by the usual mechanical plant. The combined plant, so arranged, can operate at such high rates that the costs (including fixed charges) of purifying water are as low as can be obtained by any method, and lower when there are existing slow filters to be enlarged. This, of course, can not be made as a general statement applying to all waters, but the fact is so well demonstrated on the waters for which the plants have been tried that it seems reasonable to suppose that there may be as decided an advantage on the other waters also.

As to whether the advantage exists for any particular water can be easily demonstrated by a test plant at small cost which may pay for itself a thousand times over. Where there are existing slow filters working at the usual rates of filtration, the double filtration plants operating at high rates seem extremely attractive for further extension.

The new 64 m.g.d. water purification plant at Marston Lake, Denver, of which the writer was in charge, representing Mr. Fuertes during the design, construction and early operation, has now been in use for eighteen months. Its record justifies the conclusions drawn from it and applied to similar filters used as scrubbers of a double filter plant.

CROSS CONNECTION POLICIES[1]

By Arthur E. Gorman[2]

The cross connection problem has been, during the last decade, a perennial affair in the water works field. To some who consider an issue closed with the enactment of prohibitory regulations and the establishment of administrative policies, further discussion of cross connections is repetition. Be this true or not the fact remains that the cross connection problem is still and probably always will be one with which the efficient and wide awake water works official must cope.

In its ramifications cross connection work affects many factors in our modern civilization. The health officer is primarily concerned, as the existence of cross connections jeopardizes the public health; industry is affected, as it must have assurance of a continuous and abundant water supply for its numerous processes, and the fire insurance companies assert their rights for adequate protection of the property for which they are responsible. Each group very properly asserts its rights and maintains its claims before the ever obliging water works official, who finds himself in a serious quandary.

The health officer with his broad police powers and public sympathy can prosecute a sweeping campaign against cross connections of all kinds and types; the industrial plant manager driven to distraction can usually find a political friend or two to support his case, while the fire insurance companies can always play their trump card of increased rates. With these human complications it is a wise water works official who analyzes the entire situation in a broad way and then applies certain basic principles to conditions in his own city or town and works out the rest as his common sense and conscience dictates. By this plan he may not, and probably will not, fully satisfy all concerned. The health officer may not attain a 100 per cent removal of cross connections at once; the industrial plant manager may be temporarily inconvenienced, and the fire insurance official may be compromised on his increased rate decision, but the chief object—a harmonious and intelligent study of the problem, with all eyes on the same plane—will be gained. And it is fairly safe to say that in a few years the problem will be largely solved, with the water official and his company the greatest benefactor from the whole issue.

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[1] Presented before the Indiana Section meeting, February 18, 1927.

[2] Chief Sanitary Engineer, Division of Water Safety Control, Bureau of Engineering, Department of Public Works, Chicago, Ill.

During 1924 and 1925, while the writer served as Chief Sanitary Engineer with the Chicago Department of Health, we conducted an extensive cross connection campaign, during the course of which nearly 500 illegal connections with the city water supply system were found and a wide diversity of situations was encountered. The unusual success which marked our efforts is considered almost wholly due to the strict adherence to the firm but "man to man" policies delineated by Health Commissioner Herman N. Bundesen.

While the plan for the initial surveys was being worked up one of our first thoughts was to draft a drastic cross connection ordinance with severe penalties for violations. The original of this ordinance is still in the files and as yet, outside of a regulation in the book of rules of the Division of Water Pipe Extension in the Bureau of Engineering, Department of Public Works, no legal crutch has become necessary. Generally speaking, the plan pursued was to assign inspectors to visit every plant adjacent to the Chicago and Calumet rivers and their tributaries, as well as along the lake front and other water ways. Cross connections found were brought to the attention of the engineer or plant attendant on duty and if he had sufficient authority to do so, and was so inclined, the connection was broken then and there and a final report returned and duly filed. Otherwise a letter was written direct to the managing official concerned and the potential danger of maintaining the cross connection explained, with a request for prompt authorization of its removal. In most cases where the cross connection was a minor one a favorable reply was received advising of compliance with our request. This called for a reinspection and a final "out" report. Where delays in answers or excuses developed, a personal call was made on the official of highest authority who could be reached. A very satisfactory percentage of favorable actions resulted from this policy. If the official interviewed did not possess sufficient authority to incur the expenditure necessary, this personal call usually "sold" him on the proposition or gave him sufficient first hand information to make a complete report to his superiors with favorable recommendations.

In dealing with large corporations, such as the railroads and the packing companies, it must be borne in mind that the operating and plant managing officials must receive special authority for expenditures not included in their regular budgets. In this connection a reasonable amount of patience with these officials will usually be well rewarded. Persistence and firmness are always virtues in directing a cross connection campaign and must be tactfully made evident when unusual delays develop. In some of our cross connection work in the Union Stock Yards we worked over a year before final separation of dual water systems was completed, but in the meantime a cooperative plan for disinfecting the inferior supply was worked out. Reinspections at reasonable intervals, say at least quarterly, are important in impressing the importance of the work and for effective control.

A complication common at plants where dual water supplies exist is the cross connection made by repair or remodeling contractors unfamiliar with the various piping systems. In many large institutions there is a maze of piping and when two water systems exist, even with extreme care, dangerous cross connections may be made in ignorance. Cases of this kind may easily occur where multiple piping passes through or around partitions with sharp and irregular changes in direction and pipe sizes. At some of the large packing plants in the Union Stock Yards where two and even three sources of water are used, and repairing and remodeling were almost always in progress, this complex was met by identifying the various piping systems by painting them different colors. While complete painting of all lines is preferable it is expensive and not necessary. The vital points which need identification are the branches, either side of partitions, and pump suctions and discharges.

In long pipe sections the junction points can be painted. Where pipes are covered, painting is easy and satisfactory. Uncovered pipes offer some difficulties, such as "sweating" due to condensate and peeling of the paint. In these cases sheet steel bands or flags can be attached around or suspended from the pipe. The pipe identification practice has been followed out successfully on Great Lakes' passenger vessels for four years and is being used in many of the most modern power plants in this country. As fire lines are usually painted bright red, the writer has suggested light blue as symbolic of pure or first quality city water, with yellow as re-used city water.

While the size of a cross connection has a real bearing on its importance, the degree of contamination of the inferior supply should be the basic criterion in determining the policy for its removal. It may happen that an inspector will recommend vigorous and immediate action for the removal of a 12-inch cross connection with a secondary supply of city water collected in a well protected reservoir, but overlooks a 2-inch direct cross connection with a sprinkler system through which grossly polluted river water is pumped. Obviously, the public health value of cross connection work depends on an early and complete separation of all cross connections with dangerous sources for water. In expediting this work there can be no safe compromise with double valves, etc.

Common sense is certain to be at a premium in this work. In the case of the 12-inch and 2-inch connections just mentioned it may be that the secondary source of supply is absolutely necessary for safe plant operation and the public health risk in the cross connection a mild one at best. In such a case would it not be better to be liberal with the plant management and permit, subject to supervision, for a reasonable period this 12-inch cross connection and obtain a prompt removal of the dangerous 2-inch connection?

The use of sterilizing agents such as chlorine properly controlled and supervised has, I believe, a real application in the granting of temporary cross connection permits, pending the development of an improved system. In many instances industry has suffered due to a rigid enforcement of cross connection ordinances where relief was beyond its control. For instance, when the public water service is inadequate for the industry's purpose a real problem confronts the water works official and the health officer if a satisfactory solution of the cross connection situation is to be made. Where a first class public water service is available industry is usually open to any reasonable proposition which involves the public health. If not the health officer has a clear case in his favor and cannot fail in enforcing his proper police powers.

In summarizing, the recipe I offer you for a successful cross-connection based on our Chicago experience is, first, find out the true facts; add a goodly amount of common sense seasoned by a thorough understanding of local conditions and balanced by a real appreciation of the public health values involved, after which make a direct and human appeal to the parties concerned, following up all this with an attitude of patience, persistence, firmness and fair play.

CORROSION IN A WATER SUPPLY SYSTEM AND METHODS OF PROTECTION[1]

By E. B. Stewart[2]

The subject of corrosion has not been given the consideration in the past which its importance might warrant. The lack of interest is probably due to the fact that pipe systems are, as a general rule, looked upon as practically indestructible, and when once installed require no further attention or replacement. Experience has shown, however, that pipes are always subject to corrosion and, under certain conditions, serious damage occurs in a short period of time.

Many corrosion problems have simply been looked upon as unavoidable and repairs and replacements have been made without any effort to locate and remove the cause.

The subject of electrolysis will always be pertinent so long as the running rails are used as a return path for the railway current. Improvements in rail bonding, the use of larger rails, and the more frequent distribution of substations, thereby reducing the distance that return current must travel on the rails, have been of material aid in reducing this form of corrosion.

THEORY OF CORROSION

Before taking up methods of preventing corrosion, a brief explanation will be given of the manner in which corrosion takes place, for unless there is a fair conception of the fundamental factors influencing corrosion rates, it will be difficult to know what protective methods will be most suitable.

It has been conclusively shown that corrosion does not take place to any appreciable degree unless the metal be in contact with both water and free oxygen. The action is practically nil where the metal is in contact with oxygen alone, or oxygen-free water alone. In other words, all three elements, namely, metal, water and free oxygen, must be brought in contact to cause corrosion.

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[1] Presented before the California Section meeting, October 29, 1926.

[2] Electrolysis Engineer, East Bay Water Company, Oakland, California.

When iron is placed in water, a multitude of electric potentials are immediately established between the metal ions and the electrically charged ions in the water. These potentials cause metal ions to go into the solution and set hydrogen free. This hydrogen gathers on the surface of the iron in the form of a thin invisible film and tends to retard the progress of corrosion by insulating the metal from the solution, and thus prevents further corrosion taking place. In order that corrosion may continue, the film of hydrogen must be removed. This may be accomplished by dissolved oxygen which is usually present in water combining with the hydrogen film to form water. The film having been removed, more iron can go into solution, more hydrogen can plate out and the process can continue at a rate determined by the speed with which the oxygen removes the hydrogen.

The tendency of a metal to go into solution in a conducting liquid called the electrolyte is accompanied by an electrical potential between the metal and the solution. This potential is known as its "solution pressure" or "potential pressure" and is different for different metals in contact with the same solution and also different for different solutions in contact with the same metal.

Hence when two dissimilar metals are placed in a conducting liquid, a galvanic battery is formed and the difference in potential between the metals is proportional to the difference in their "potential pressures." When the metals are connected by a wire, an electric current will flow through the wire between the metals, and the electropositive metal will corrode at a rate inversely proportional to the resistance of the circuit. Therefore, the rate of corrosion will be a maximum when the metals are brought in physical contact, which is usually the case in practice. In this case the circuit will be completed internally through the metals.

Corrosion resulting from contact of dissimilar metals is commonly called "galvanic action." This form of corrosion is often not generally understood, probably because it occurs under conditions difficult to study.

An example illustrating the effect of corrosion from this cause in practice is found in the destruction of our service pipes at the union connecting the lead goose neck. Many cases have been found where the service pipe shows general corrosion immediately adjacent to the union. The service pipe is the electropositive metal, hence a galvanic current will flow from the pipe to the union, resulting in corrosion of the former.

An insulating bushing placed between the pipe and the union was found to be the most economical method of preventing this type of galvanic corrosion. The electrical circuit is thus broken and the corrosion hazard is eliminated. This insulating medium also prevents the flow of stray railway currents.

There are many cases where it is impracticable to insulate dissimilar metals from physical contact with each other, particularly in well pumping equipment. In this case, it is desirable to select materials that are most uniform in texture. In some cases where cost is an important factor and the extent of the corrosion is limited, it may be advisable to select such combinations of metals as to make the least expensive metal electropositive and the most expensive electronegative.

SOIL CORROSION

Natural soil corrosion is sometimes spoken of as "self corrosion" to distinguish it from corrosion due to externally applied electric currents.

On the whole, corrosion in soils is similar to corrosion in water, because the controlling factor in soil corrosion is water. For in the absence of water, no corrosion will take place. But since pure water does not corrode iron appreciably, it is obvious that the corrosive character of the soil depends primarily upon the presence of certain dissolved materials in the soil water, which originate both from the air and from the ground. In other words the soil is an electrolyte of widely varying concentrations due to the many factors present such as soluble salts, acids, dissolved gases, etc., which make a solution of high electrical conductivity and hence more stimulating to corrosion than pure water.

There are certain physical properties of pipes which have more or less influence on the corrosion rate, such as character and uniformity of the surface finish of the metal, segregation of impurities in the metal, composition of the metal, area of the metal exposed as anode, parts of the metal that have been scratched or bruised from rolling, hammering or threading. Some of these factors influence the total amount of corrosion. For instance imperfections in mill scale will cause pitting which is the most destructive form of corrosion. Mill scale is electronegative to iron, and hence galvanic action takes place between them when in contact with a conducting solution.

It is obvious that differences of potential exist between points on the pipe surface that are in contact with soils of different concentration, since it is known that the "potential pressure" of a metal is different for different solutions. It follows, therefore, that galvanic currents will flow through the pipe between different points of concentration on the pipe surface, entering the pipe at points of low concentration and leaving the pipe at points of high concentration, causing corrosion at points where current leaves the pipe. That corrosion does occur in accordance with these conditions has been verified by the writer by placing non-polarized electrodes about six inches apart at right angles to a steel pipe and noting the difference of potential between them when one electrode is very close to the pipe. Two points were located three feet apart where current was flowing away from the pipe at one point and entering the pipe at the other. An examination of the pipe indicated that corrosion was in progress at the point where current was leaving the pipe, while the pipe was found in good condition where current was entering.

This brings out the fact that corrosion is stimulated when parallel mains are laid in close association with each other for the pipes act as conductors to complete a galvanic circuit between points of different concentrations in the soil. To illustrate the effect of corrosion under these conditions, a steel pipe laid eighteen inches distant from a parallel sixteen-inch main that was abandoned, showed with an earth current meter a relatively large galvanic current leaving the pipe toward the abandoned pipe at a point where serious corrosion was in progress. When the abandoned pipe was removed, this point became negative to the earth, thus preventing further corrosion. We have found from earth current measurements that pipes laid parallel in the soil should be at least four feet apart in order to prevent the flow of destructive galvanic currents.

One of the outstanding problems that confronts water works people, together with all other utilities owning underground pipes, is the development of improved means whereby the corrosive power of certain soils may be determined. If it were possible to determine the corrosive power of the soil, it would be possible to determine what form of protection, if any, would be most suitable for a particular kind of pipe at a minimum cost. The present knowledge of the corrosiveness of any particular soil is based largely on practical experience of the corrosion of pipes in similar soils.

In 1922 the American Committee on Electrolysis and the National Bureau of Standards in coöperation with a number of pipe manufacturers buried thousands of small samples of different kinds of pipe in about forty locations widely distributed throughout the entire country, to obtain a further knowledge of the effects of different kinds of soil on the corrosion of buried pipes. All kinds of soil and climatic conditions have been included in the tests. It is the plan to submit tentative reports as fairly definite results develop. The whole investigation is being carried out by the Bureau of Standards and is being watched with great interest by the manufacturers and users of pipe.

Our investigations of the corrosiveness of soils indicate that very little corrosion occurs in soils having a resistance over 1000 ohms per cubic centimeter.

PREVENTIVE MEASURES FOR SOIL CORROSION

Damage to pipes by soil corrosion may be prevented by two methods: (1) Covering the pipe surfaces to insulate them from the earth. (2) Making pipes negative to earth by external current or by the application of more anodic metals. This method is known as cathodic protection.

In the study of soils to determine the type of coating necessary to prevent soil corrosion, stray current from railway tracks should be taken into consideration. For instance, no coating is necessary on pipes located on railway lines where the potential of the pipes is negative to the rails regardless of the kind of soil, because it is well known that no corrosion takes place where pipes are negative to the earth. In some cases we have made small pipes negative to earth by connecting zinc plates to the pipe at intervals determined by earth current measurements. The plates are buried in the soil approximately one foot from the pipe. Insufficient data are available at present to determine the probable life of such protection, but, from all indications, it appears to have some merit as a temporary expedient in localized cases.

ELECTROLYSIS

Corrosion from stray current is of special importance in cities where buried metallic conductors come in more or less close association with electric railway systems. The chief factors involved in dealing with stray current electrolysis comprise the testing for, and the control of, stray currents responsible for the damage.

The majority of the street railways of the country are operated on the single trolley system using the rails to return the current back to the power station. The total current, however, will not return to the power station by the rails; a part of the current will shunt from the rails to earth in the negative area and find its way to nearby networks of metallic underground structures and flow on them in a general direction toward the substation. As the station is approached, the current tends to leave the structures to earth and return to the rails. Corrosion will take place where these currents leave the pipes to earth.

Experience has shown that stray currents also leave the pipe in the negative zone at remote distances from the ends of the car lines, a condition which is somewhat contrary to the usual explanation of the flow of stray currents. This condition is made possible by two separate tracks leading from the same power house and laid out in such a way that the return of one line is almost without loss of potential, while the other has considerable loss. In this case part of the current will leak across through the earth to the track which is without loss of potential. These currents will accumulate on the pipes running in the same general direction and very often cause rapid corrosion.

An example of corrosion from stray current in accordance with these conditions was found at a point one mile distant from the end of the nearest railway line. Earth current measurements showed an average current of six milliamperes leaking to earth from every square foot of pipe. This is an unusually high leakage current, when it is considered that leakage values below 0.5 of a milliampere per square foot are considered safe.

MEASURES TENDING BOTH TO RAILWAY ECONOMY AND THE REDUCTION OF STRAY CURRENT

The magnitude of stray currents is determined by the design, construction, maintenance and operation of the railway system. In the effort to eliminate the corrosion from stray railway current, the most logical procedure is to attack the trouble at its source, the production of the stray currents.

An analysis of the power distribution and the operation of the railway is the most essential factor to consider when making electrolysis surveys.

The question of electrolysis has been very actively studied for a number of years by the "American Committee on Electrolysis" which was formed from representatives of the various public utility associations whose interests were affected. Most members of this Association are probably familiar with the report of the Committee issued in 1921.[3] This report represents the unanimous opinion of the representatives of all the different interests involved.

A matter of particular concern is the study and development of railway distribution. Considerable progress has been made in recent years in the development of automatic, semiautomatic and remote control substations, and these are now being used on both city and interurban lines. The economic operation of such substations makes possible a greater number of feeding points than can economically be supplied through manually operated stations. The increase in the number of substations will obviously reduce the feeding distances, and effect a saving in distribution copper and in line and return losses. The general effect is the reduction of track voltage drops; thereby reducing the leakage of stray current into the earth.

This is a very important development in railway operation for the protection of damage to pipes from electrolysis, as the same factors that determine economy of railway operation also control the leakage of stray currents to earth.

Within the last year, four additional substations have been added to the local railway system within the territory affecting our piping system and recent surveys show that such measures have materially reduced stray currents in the piping systems.

REMEDIAL MEASURES APPLICABLE TO AFFECTED STRUCTURES

The principal measures used by this Company to eliminate or reduce corrosion from stray current are: (1) Electrical drainage; (2) insulating joints; (3) electrical connections between pipes in close association.

Electrical drainage

Electrical drainage is used to drain enough current to make the pipes negative to the earth in the vicinity of negative feeder connections. While electrical drainage is not considered good practice by many engineers, nevertheless, under certain conditions, it appears to be the best temporary expedient consistent with economy. Where large mains are already in place, it seems logical to apply a limited amount of drainage until such time as remedial measures can be applied to the railway system. Electrical drainage is applied in coöperation with other utilities through committee activities which will be discussed later in this paper.

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[3] Summarized in the Manual of Water Works Practice.

Where drainage systems are in use, very careful surveys and inspections must be made at frequent intervals, if adequate protection is to be realized, as changes and extensions to either railway or underground systems will establish added points of hazard.

Care must be taken to avoid unequal drainage between pipes that are in close association. The drainage of one system of pipes will, of course, lower its potential with respect to the neighboring pipes tending to injure the latter. This in turn calls for drainage of the injured system which may in turn damage the first or other structures and consequently a system of competitive drainage is established.

Overdrainage of cable systems is very often a hazard to pipe structures. Pipes as a rule are much closer to cable conduits in the ground than they are to rails. In many cases, the pipes are resting directly against the conduit. Under such conditions where both metals are in wet soil, it is possible for large leakage currents to flow and cause damage to the main or service pipe. In one particular instance, overdrainage of cable systems caused serious damage to one of our transmission mains on a street where no electric railway tracks exist. This condition brings out the fact that potential measurements between pipes and cables should not as a rule be confined to streets having railway tracks.

Insulating joints

Insulating joints are used in new pipe lines and some existing lines in negative and neutral zones with particular reference to those points where it is expected that large transverse currents are flowing between parallel rails due to unusually high voltage drops between them, or where it is expected that currents will be transmitted to and discharged from the pipes in soils of low electrical resistance. In the insulated sections, the service pipes are prevented from making electrical contact with other piping systems by the use of insulating joints at the meters. Without insulating joints in the service pipe, stray current could enter from the other piping systems through gas water heaters and other appliances with which it comes in contact and injury would result to both the service and the section of the main to which it connects. It is often necessary to install insulating joints on cross mains which connect the insulated sections. We have found from laboratory studies, together with studies in the field under working conditions, that cement used as an insulating medium offers the highest electrical resistance to the flow of stray current, and when joints are placed at regular intervals of approximately 100 feet, the current flow on the pipe lines is reduced to relatively small values. Resistance measurements of a number of insulating joints that were in service for approximately three years, showed an average electrical resistance of 0.6 ohms in soils having a resistance below 1000 ohms per cubic centimeter. In many cases the resistance of an insulating joint is greater than the resistance of 400,000 feet of pipe.

The principal objection that has been raised to the use of insulating joints is that corrosion is apt to occur on the positive side of the joint. During the last four years we have engaged in regular tests and inspections for joint corrosion and to date no corrosion from this cause has been located. Such installations might fail to protect the pipes in many instances because of the too infrequent use of insulating joints, especially if the pipe line is laid parallel with high potential gradients in the earth.

For example, in a case, where the difference of potential in the earth is, say, ten volts per 1000 feet, and a pipe line is located in a direction approximately parallel to the electromotive force, heavy currents will, as a rule, be picked up by the pipe, and if this is discharged into the earth, serious damage will, of course, result. If the continuity of the pipe is broken up by inserting insulating joints, then practically all of the potential drop would be concentrated at the joints. For instance, if two insulating joints are inserted in a pipe 1000 feet in length, the drop across each joint will be approximately five volts.

Since the leakage path around such joints is usually very short, it is evident that high voltage potentials will produce a correspondingly high current density across this short distance in soils of low electrical resistance, and, as a consequence, sufficient currents will flow around the joints to destroy them within a comparatively short time. It is evident that in order to prevent this, a sufficient number of insulating joints must be used so as to reduce the current density around the joints to a practical minimum. In other words, the frequency that insulating joints may be placed to secure adequate protection against electrolysis is determined by two factors, namely, potential gradients in the earth and electrical resistance of the soil.

To illustrate a practical example of the effectiveness of insulating joints, a sixteen-inch non-insulated steel pipe having been destroyed beyond repairs after less than three years' service was renewed with the same size and kind of pipe with insulating joints placed at regular intervals of 100 feet. This pipe has been in service a little more than four years, and to date, it has not suffered damage from electrolysis, although subjected to the same stray current conditions

Earth current meter

The most difficult part of an electrolysis survey, perhaps, consists in drawing proper conclusions. No one set of measurements will suffice as a basis. While potential measurements represent the tendency to produce stray currents, the currents which cause the damage are determined as well by the resistivity of the soil, which varies over wide limits from one part of the city to another. Currents flowing in the pipes will be affected by the relative location of the pipes and the rails in the streets. Services or mains passing very close to the rails will have large stray currents, and these currents are likely to leave over restricted areas, causing more concentrated corrosion. The current strength in pipes cannot always be used as an index of electrolysis hazards. Relatively large currents may be flowing on a pipe without causing any corresponding damage for these currents do not flow to the soil. On the other hand, relatively small currents may be flowing along the main and yet corrosion may be taking place.

Heretofore our greatest difficulty encountered in electrolysis testing has been our inability to measure directly the factor responsible for the corrosion, namely, the density of the current flowing from a pipe to earth. It was evident, therefore, that there was a need for improved means of electrolysis testing, whereby it would be possible to determine the polarity of the pipe with respect to earth, and for the quantitative measurement of current density at any desired point in the earth.

An earth current meter was developed by Burton McCollum of the United States Bureau of Standards and was described in some detail in The Electric Railway Journal of November 21, 1921. This instrument enables one to determine the actual density of current discharge from the pipe which is measured in terms of milliamperes per square foot of pipe surface. We have used this instrument for electrolysis testing for the past two years and have found it to be well adapted for use under practical conditions. By the use of this instrument, information can be had showing far more definitely the actual electrolysis conditions prevailing on any particular point than it is possible to secure by any other means heretofore available. This instrument is the best means available whereby it is possible to differentiate between natural soil corrosion and corrosion from stray currents.

COÖPERATIVE TREATMENT OF ELECTROLYSIS PROBLEMS

When stray current flows into the earth, many different utilities owning underground structures are affected. The problem of electrolysis, therefore, is one which is preëminently adapted to coöperative treatment. When each interest cares for its problems independently, then each is partly undoing the work of others and a condition arises where money is being spent in producing systems that afford only temporary relief.

Such a condition is to be found where each utility attempts to apply a drainage system independent of all other utilities. It is easy to understand how confusion often arises when, say, three companies apply drainage systems independent of each other, and large differences of potential exist between them. The three systems are in many ways in conflict, and very often rapid corrosion takes place.

Troubles in various utilities finally reached a point when it was realized that stray electric currents could be best controlled by coördination of effort on the part of all interests. As a result a committee of representatives of all interested utilities in the East Bay Cities was organized in 1922 to determine the causes of damage to underground structures and recommend measures for their mitigation through means of coöperation among the interests concerned. Such assistance in the way of testing instruments, engineers, draftsmen, field employees, transportation and office space are contributed by the various member organizations. This committee holds monthly meetings to discuss the technical phases in connection with reports of tests and investigations that have been made during the current month and makes recommendations for protective measures. It recommends tests and investigations to be made and indicates the methods to be followed in making such tests and investigations.

Regular surveys are made of the railway systems and the various underground structure systems, and include such measurements as: current of station loads, rail gradients, overall potentials, difference of potential between rails and underground structures, current on underground structures, difference of potential between different structures and earth current measurements. These tests comprise to date over 2000 twenty-four hour recording charts and 6000 readings from indicating meters. Test on railway systems required over 800,000 feet of wire which had to be strung on pole lines.

In addition to regular tests, this committee also investigates special cases of corrosion and installs pilot wires and drainage cables. Many serious cases have been corrected through committee activities at a minimum of expense to the interests affected.

The work of this committee has rendered valuable service in the installation and maintenance of drainage systems. An agreement was reached whereby drainage cables from the various underground structures were run to the most convenient manhole, either telephone or electric light, and these connected to the negative return on a common bus bar. Such an arrangement makes it possible to insert resistance grids in series with drainage cables in order to equalize the potential between various underground structures.

This committee makes monthly tests of return current on all drainage systems as a precaution against damage from broken drainage connections or unusually large currents being drained due to changes or additions to the various structures. Tests are taken periodically to check the voltage conditions existing between the various structures, and steps are immediately taken to correct any dangerous conditions that might be found.

Coöperative treatment of electrolysis problems has been proven successful in a number of cities throughout the country, and is now generally recognized as representing the best practice in electrolysis prevention.

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POTENTIOMETRIC DETERMINATION OF HYDROGEN ION CONCENTRATIONS IN BOILER WATERS[1]

By Willard N. Greer[2] and Henry C. Parker[2]

The dissociation of water into its constituents, hydrogen ions H^+, characteristic of acids, and hydroxyl ions ^-OH, characteristic of bases, has an important bearing on the properties of salts in solution. According to the kinetic theory, the process is such that, at equilibrium, the rate of formation of the ions from the water molecules is equal to the rate of recombination of the ions. Expressing the equilibrium mathematically, we have:

$$\frac{[H^+] \times [OH^-]}{[HOH]} = k$$

where the brackets [ ] indicate concentrations. Since water is only slightly ionized, the concentration of the undissociated water, [HOH], may be considered a constant at a given temperature, and combined with k. The above equation then becomes:

$$[H^+] \times [OH^-] = K \qquad (1)$$

The constant K has been determined, by a variety of methods, to be 10^{-14} at 22°C. The value of K increases considerably at higher temperatures.

The introduction of an acid into water increases the hydrogen ion concentration, and the introduction of a base increases the hydroxyl ion concentration. In either case, assuming the law of mass action to hold, the equilibrium condition is such that, under the same temperature conditions, equation (1) applies. These considerations show that, whatever the concentration of hydroxyl ions, there are always hydrogen ions present, and we may speak of the hydrogen ion concentration of a solution which is really basic.

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[1] Presented before the Boiler Feed Water Studies meeting, Buffalo Convention, June 9, 1926.

[2] Research Department, Leeds & Northrup Company, Philadelphia, Pa.

HYDROLYSIS OF SALTS

The temperature and the constituents of a salt, MeX, determine the degree of hydrolysis in solution. Both anion and cation can react with the ions of water:

$$Me^+ + HOH \rightleftarrows MeOH + H^+ \qquad (2)$$

$$X^- + HOH \rightleftarrows HX + OH^- \qquad (3)$$

The salts of strong acids and strong bases are largely dissociated. Since such salts are not hydrolyzed to any appreciable extent, the hydrogen-ion concentration of their solutions is about 10^{-7} at ordinary temperatures. Acids and bases affect the hydrogen-ion concentration of such solutions in the same way as that of pure water.

A salt of a weak base and a strong acid will react according to equation (2) and the solution will have an acid reaction. A salt of a strong base and a weak acid will react according to equation (3) and the solution will have an alkaline reaction. In titrating a solution of magnesium chloride, $MgCl_2$, it is evident that sufficient alkali would have to be added to neutralize the HCl formed by the hydrolysis. A similar effect is caused when making an alkalinity determination of a carbonate, such a solution requiring additional acid to neutralize the $Ca(OH)_2$ formed by the hydrolysis.

It is evident that the true neutral point of a solution occurs when $[H^+]$ and $[^-OH]$ are equal, and have a value of 10^{-7} at ordinary temperatures (equation 1). The end point with phenolphthalein, however, occurs when the hydrogen ion concentration is approximately 10^{-8}, and that with methyl orange when the hydrogen ion concentration is approximately 10^{-5}. This shows that when hydrolyzable salts are present a titration with indicators is only an approximate method of determining the acidity or the alkalinity of a solution. A titration may be said to give a measure of the *available* acidity, while hydrogen ion measurements give the true or *actual* acidity of a solution. It is the latter factor which determines the *reactivity* of a given solution. Hence the measurement of *ion* concentration will undoubtedly be necessary before any definite relation can be established between the concentration of boiler chemicals and caustic embrittlement, foaming, corrosion, formation of scale, and other boiler phenomena.

Instead of expressing the hydrogen ion concentration as a negative exponent, Sorensen suggested the use of the term pH, the pH value being the logarithm of the reciprocal of the hydrogen ion concentration, $\mathrm{pH} = \log \frac{1}{[\mathrm{H}^+]}$. A neutral solution then, has a pH of 7, and the end points of phenolphthalein and methyl orange occur approximately at a pH of 8 and 5, respectively. A solution normal with respect to hydrogen ions has a pH of 0, while a solution normal with respect to hydroxyl ions has a pH of 14.

At the higher temperatures and concentrations the measurements of the ion concentrations become of increasing importance due to the fact that the ionization of electrolytes decreases considerably at these temperatures.[3] This is especially true of the more complex salts, since the ionization of such salts falls off more rapidly than does that of the binary salts. Measuring the hydrogen ion concentration of boiler water at ordinary temperatures does not give a measure of this value at boiler temperatures, but it is usually a much more valuable measurement than the "alkalinity" at ordinary temperatures. (Of course an alkalinity determination at ordinary temperatures does not give a true measure of the alkalinity at boiler temperatures.) The latter does not take into account the presence of salts which may hydrolyze at the higher temperatures and thereby supply sufficient acid for corrosion. Hydrogen ion measurements, on the other hand, do make allowance for these salts, due to their so-called "buffer" action. By "buffer" action is meant the resistance exhibited by a solution to change in pH upon the addition of alkali or acid.

A simple experiment is cited to illustrate the relation between alkalinity and pH of a solution containing a hydrolyzable salt. If just sufficient sodium hydroxide is added to distilled water so that on boiling the solution will remain pink to phenolphthalein, and then a solution of magnesium sulfate, for instance, is treated with sodium hydroxide to give the same alkalinity, the color of the latter will disappear on boiling. If, however, the magnesium sulfate solution is treated with sufficient sodium hydroxide to bring it to the same pH as the sodium hydroxide solution, the former will give a pink color with phenolphthalein on boiling. The results of such an experiment are tabulated below.

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[3] Kraus, The Properties of Electrically Conducting Systems, p. 151. The Chemical Catalogue Company, N. Y.

Distilled water with NaOH

Alkalinity = 0.9 cc. H_2SO_4
pH = 9.65
(Pink to phenolphthalein on boiling)

$MgSO_4$ solution

Added NaOH to give alkalinity = 0.9 cc. H_2SO_4 (color disappeared on boiling)
Added NaOH to give pH = 9.65 (color remained on boiling)

Sample of boiler water

Added H_2SO_4 to give pH = 9.65 (color remained on boiling)
Added H_2SO_4 to give alkalinity = 0.9 cc. H_2SO_4 (color disappeared on boiling)

This experiment shows that a boiler, freshly filled with condensate, requires only a small fraction of the alkalinity which is required after the normal accumulation of salts. Control of the boiler water to a given pH would accomplish this. Hence, in cases where the pH of the boiler water is normally kept at a pH of 10.5 or below, it is probable that this type of control would be more satisfactory than alkalinity control. Above a pH of 10.5 the H-ion measurements would probably be found too insensitive.

The large buffer action of a small quantity of salts in water is further shown by a table given by Wilson,[4] who found that, in order to raise Cambridge tap water to a pH of 10, it was necessary to add 40 p.p.m. of sodium hydroxide, while the same requirement for distilled water was only 13 p.p.m. Thus, if the pH of this water, considered as boiler feed water, had been kept constant by hydrogen ion control, there would have been added 27 p.p.m. of caustic to allow for the salt content of the tap water. On the other hand, if the control had been by an "alkalinity" determination, no such allowance would have been made, and the salts would have gone into the boiler with no alkali to compensate for the acid liberated on hydrolysis at high temperatures.

It is not claimed that the excess caustic that would be added by hydrogen ion control would be just sufficient to neutralize the acid liberated at boiler temperatures, but this allowance would be approximately correct for the following reason. It is well known that the salts which hydrolyze slightly at normal temperatures are the ones which exert the greatest buffer action. Thus the content of sodium chloride would have very little effect on the amount of caustic

[4] Jour. Ind. Eng. Chem., *15*, 128 (1923).

required to bring the boiler feed water to a given pH value. On the other hand, a salt like magnesium chloride would have a much greater "buffer" action and this is the type of salt which would be expected to liberate acid at the higher temperatures.

HARDNESS, ALKALINITY AND pH

The method of determining hardness by the soap test was first proposed by Clark.[5] This method, at best, is only an approximation, and has been criticized by various writers.[6] Especially is this method in error in waters containing appreciable amounts of magnesium. A few samples of water containing known amounts of calcium and magnesium chlorides, in the ratio of two to one, were tested for hardness by the soap method, and it was found that the results were from 30 to 35 per cent low. The results obtained might be termed the "apparent hardness."

The results obtained on treating solutions of calcium and magnesium chlorides, and samples of water from three different rivers, with sodium carbonate and hydrochloric acid, respectively, are shown in figure 1, where the apparent hardness is plotted as abscissae and the pH as ordinates. Curve S was plotted from data obtained on a sample of water from the Schuylkill River, curve W from a sample of the Wissahickon Creek, curve D from a sample of the Delaware River, curve A from a solution containing 0.475 gram of $CaCl_2$ and 0.235 gram of $MgCl_2$ per gallon of distilled water, and curve B from a similar solution containing 0.235 gram of $CaCl_2$ and 0.115 gram of $MgCl_2$ per gallon. Air was previously bubbled through these solutions for a few minutes, to produce as nearly as possible the condition of natural water. The initial pH and alkalinity of each sample is indicated by the point between the arrows, addition of sodium carbonate resulting in an increased pH, and addition of HCl resulting in a decreased pH. It is evident from these curves that the apparent hardness is practically independent of the pH between pH 4 and pH 7.5. It might be said that all waters are hard below pH 3.

There is a more or less general relation between the pH and the alkalinity of natural waters. This is indicated by figure 2, where the pH is plotted as ordinate and the alkalinity as abscissa. The

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[5] Chemical Gazette, *5*, 100 (1847).

[6] Hehner, Analyst, *8*, 77 (1883). Pfeiffer, Z. angen. Chem., 193 (1902). Proctor, Jour. Soc. Chem. Ind., *23*, 8 (1904).

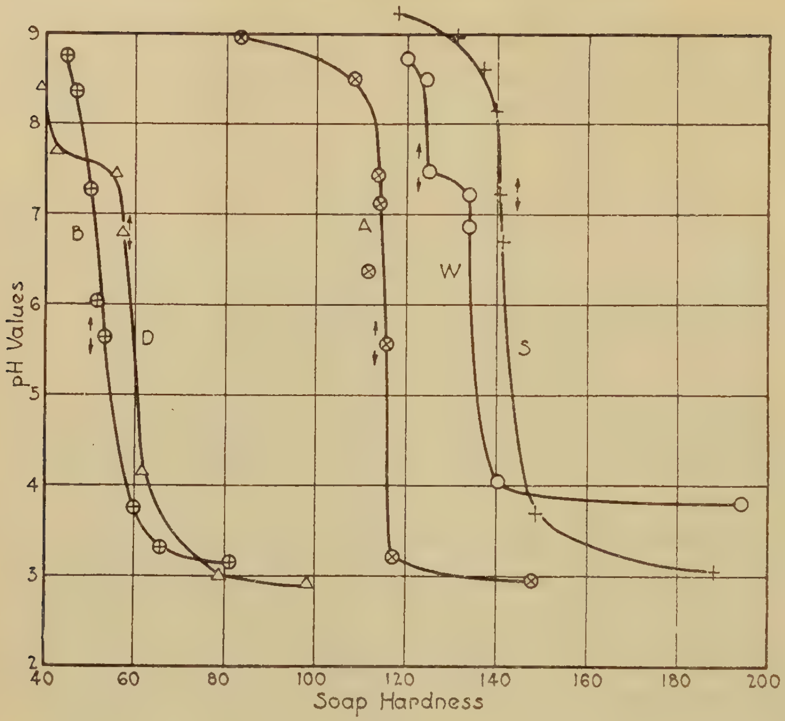
pH Values
Soap Hardness
9
8
7
6
5
4
3
2
40
60
80
100
120
140
160
180
200
B
D
A
W
S

FIG. 1

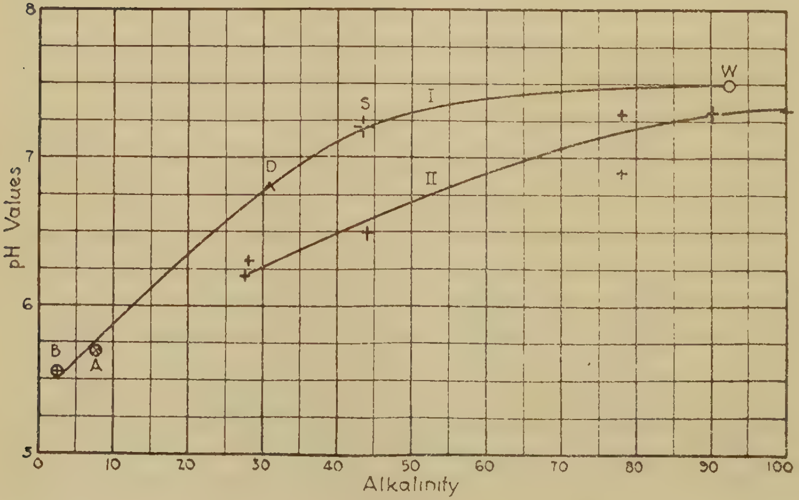
pH Values
Alkalinity
8
7
6
5
0
10
20
30
40
50
60
70
80
90
100
B
A
D
S
I
II
W

FIG. 2

points *W*, *S* and *D*, curve I, represent these values as determined from samples of the Wissahickon Creek, Schuylkill and Delaware Rivers, respectively. Points *A* and *B* were determined from solutions containing calcium and magnesium chlorides in distilled water, the composition of *A* being 0.475 gram $CaCl_2$ and 0.22 gram $MgCl_2$ per gallon, and that of *B* 0.235 gram $CaCl_2$ and 0.115 gram $MgCl_2$ per gallon. Curve II was plotted from data by Greenfield and Baker[7] obtained on three different rivers in the Middle West.

ELECTROMETRIC DETERMINATION OF H-ION CONCENTRATION

The electrometric method is the fundamental method of determining hydrogen ion concentrations. Other methods of determining H-ion concentration are referred to the electrometric method as a standard. Colorimetric methods give approximate values and may be used where only rough measurements are desired. Of course, colorimetric determinations cannot be used where a continuous record of H-ion concentration is desired, but may be used as a rough check on electrometric determinations. The electrometric method of measuring H-ion concentration consists in measuring the voltage developed when suitable electrodes are immersed in the solution. It is beyond the scope of this paper to discuss in detail the derivation of the equations relating to pH and the potential difference between electrodes.[8] It will be sufficient to give a few fundamental relations.

The fundamental reference electrode is the hydrogen electrode. A noble metal, platinum generally being used, coated with platinum black may be made to serve as a hydrogen electrode. When it is saturated with hydrogen and immersed in a solution containing hydrogen ions, there is exhibited a difference of electrical potential between solution and electrode which is dependent upon the concentration of hydrogen ions. We have no means of measuring such a single potential, but if we have two such electrodes, in separate containers and connected by means of a "salt bridge," we can measure the total E.M.F. We can show how this E.M.F. varies with the concentration of hydrogen ions from a derived equation.

$$\text{E.M.F.} = 0.000{,}198{,}37\ T \log \frac{C}{C'}$$

where T is the absolute temperature, and C and C' are the H-ion concentration.

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[7] Jour. Ind. Eng. Chem., *12*, 990 (1920).

[8] For a complete discussion see, Clark, The Determination of Hydrogen Ions. Williams and Wilkins, Baltimore.

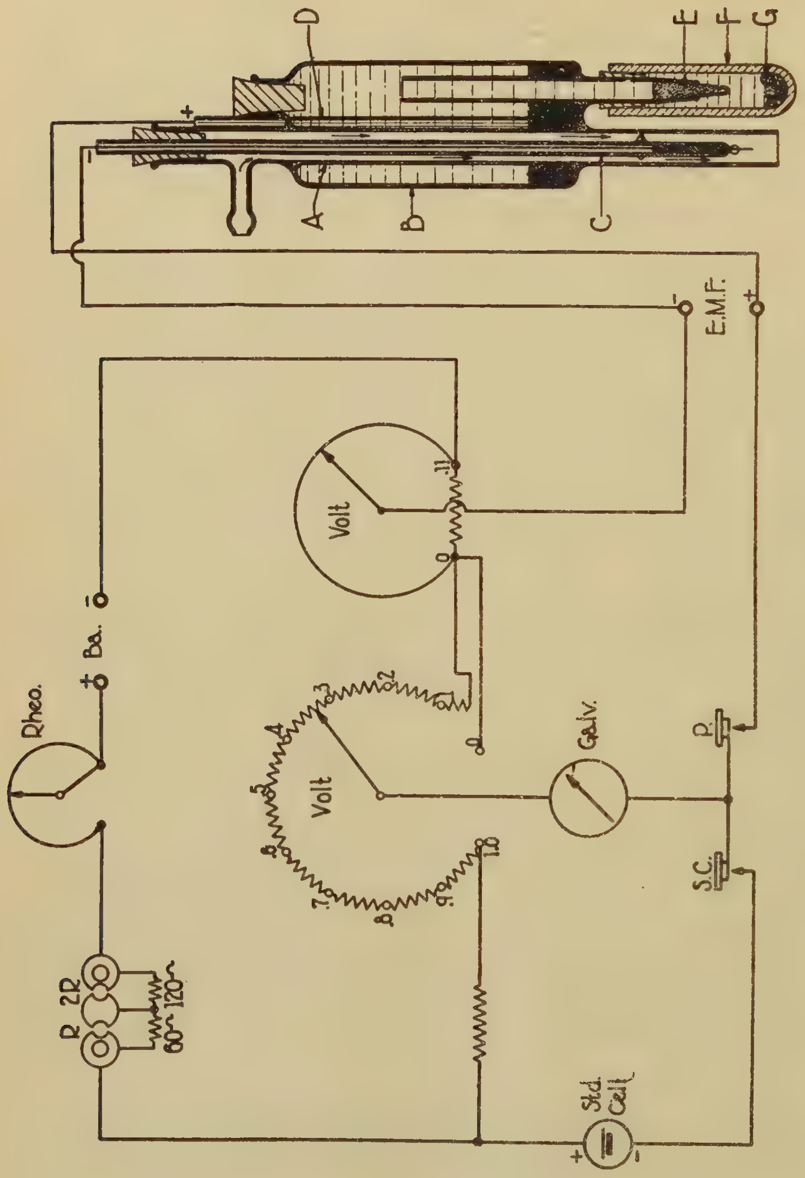

FIG. 3. DIAGRAM OF POTENTIOMETER CIRCUIT AND ELECTRODES

If measurements are carried out at 25°C. the equation becomes E.M.F. = $0.0591 \log \frac{C}{C'}$.

Instead of using two hydrogen electrodes it is more convenient to replace the standard hydrogen electrode with a calomel electrode. This is an electrode of mercury covered with calomel (Hg_2Cl_2) in the presence of a definite concentration of potassium chloride. A saturated solution of potassium chloride is generally used in industrial measurements, since there is less tendency for diffusion to change the concentration, its conductivity is high, and it shows no change in electrode potential between 5° and 60°C., except that which can be corrected by the temperature coefficient. At 25°C. the mercury of the calomel electrode is 0.246 volt more positive than the platinum of the normal hydrogen electrode. The voltage of the calomel electrode does not vary with changes in the hydrogen ion concentration of the solution, as does the hydrogen electrode. The equation becomes:

$$\frac{\text{Observed E.M.F.} - 0.246}{0.0591} = \text{pH} \tag{4}$$

As a means of measuring the E.M.F. between two such electrodes, a potentiometer is used. The outlines of a combined type of calomel electrode and hydrogen electrode[9] and a diagram of a potentiometer circuit are shown in figure 3. Electrical connection to the calomel electrode is made through *D*, and to the hydrogen electrode through *C*. The hydrogen is bubbled in through the tube *A*. *F* is a porous cup containing a saturated solution of KCl above a few crystals of KCl, *G*, and forms a salt bridge to the calomel electrode, liquid connection being made through the ground glass plug *E*. To measure the voltage of the electrodes it is only necessary to immerse the combined cell in the solution to a depth sufficient to cover the platinum electrode, bubble hydrogen through the solution around the electrode, and read off the voltage with the potentiometer. The voltage reading may be converted to pH units by means of equation (4), by an H-ion calculator, or read off directly from a pH-voltage chart, figure 4. Such a cell is used for intermittent measurements. The potentiometer can be made to read in volts, or directly in pH units.

ELECTRODES

The hydrogen electrode is the only electrode which will cover the entire pH range but, unfortunately, is not suitable for use in a flowing solution without some method of presaturating the solution with hydrogen. There are several substances which have been found to "poison" this electrode, such as oxidizing substances, some organic compounds, and ions of metals more "noble" than hydrogen. There are, however, a great many industrial processes in which the hydrogen electrode is applied, among which might be mentioned tanning, baking, etc.

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[9] Parker and Dannerth, Ind. and Eng. Chem., *17*, 640 (1925).

The tungsten electrode[10] is apparently the most free from poisoning effects. It is best used in a flowing solution, and is adapted for intermittent measurements only by following a definite procedure. Its accuracy, however, is not greater than ±0.1 pH, and it is not satisfactory for use in solutions more acid than pH 5. A flow channel carrying a saturated calomel cell and tungsten electrode is shown in figure 5. The pH-voltage relations of the tungsten electrode are shown in figure 4.

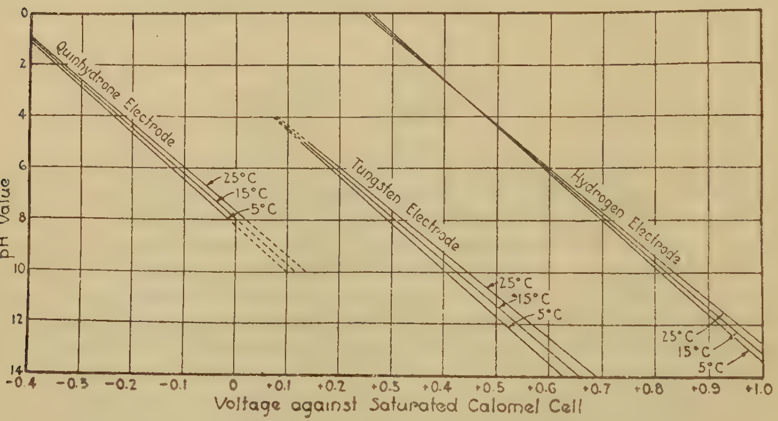

FIG. 4

For intermittent measurements the procedure used is to keep the electrode immersed in a stable buffer solution of approximately the same pH as that of the test solutions, removing the electrode only during the time of use. When used in a flowing solution an electrode is introduced into the cell (or is placed in a buffer solution) twenty-four hours before being connected to the recorder. Experience determines how often, in general, a new electrode will have to be introduced. The usual life of the tungsten electrode in boiler feed water is two weeks.

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[10] Baylis, Jour. Ind. Eng. Chem., *15*, 852 (1923). Parker, Jour. Ind. Eng. Chem., *17*, 737 (1925). Parker and Baylis, Jour. Amer. Water Works Assoc., *15*, 22 (1926).

The quinhydrone electrode[11] is not so subject to "poisons" as is the hydrogen electrode, but is not applicable in solutions more alkaline than pH = 8. In a few cases measurements may be made in more alkaline solutions, provided the measurements are made quickly and the first reading is taken as being correct. With this

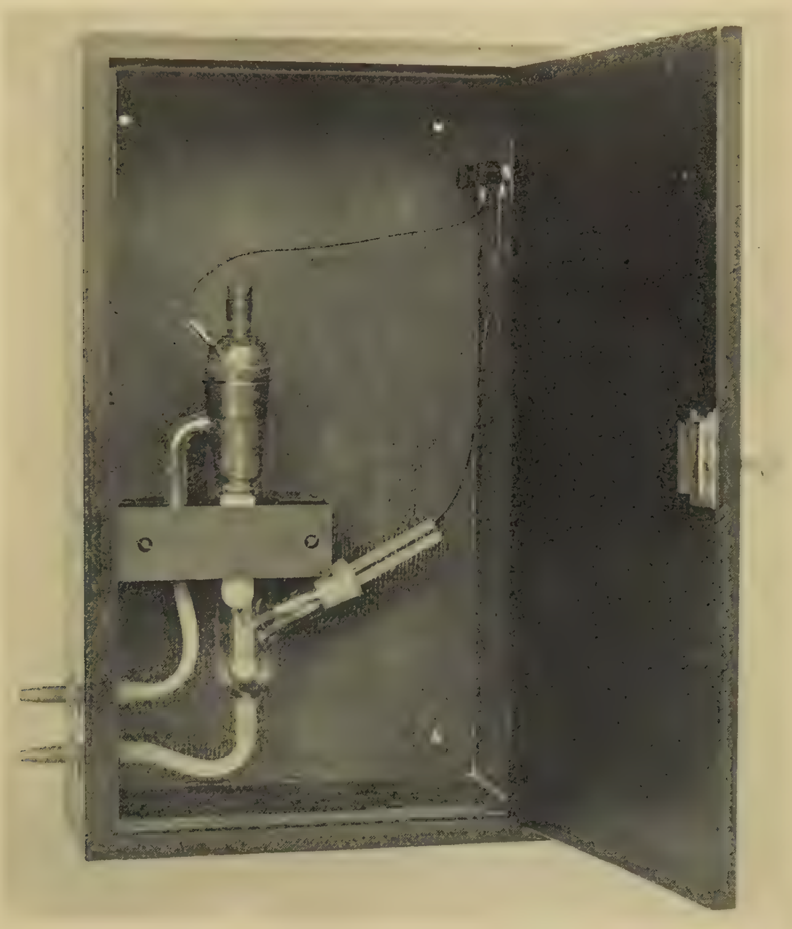

Fig. 5. Flow Cell

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[11] For bibliographies on the quinhydrone electrode see, Billman, Trans. Faraday Soc., *19*, 676 (1924), or Kolthoff and Furman, Potentiometric Titrations, p. 220, John Wiley & Sons, N. Y.

electrode an error is introduced, if there is a high concentration of salts present, but this error is always in the same direction. This fact does not prohibit its use in such a case, since the relative value will remain the same, if a series of measurements are made. The combined type cell, figure 3, may be used for a quinhydrone electrode,[12] (a gold electrode is recommended in place of platinum) if a few cc. of saturated quinhydrone solution, or a few crystals of quinhydrone, are added to the test solution. The quinhydrone electrode

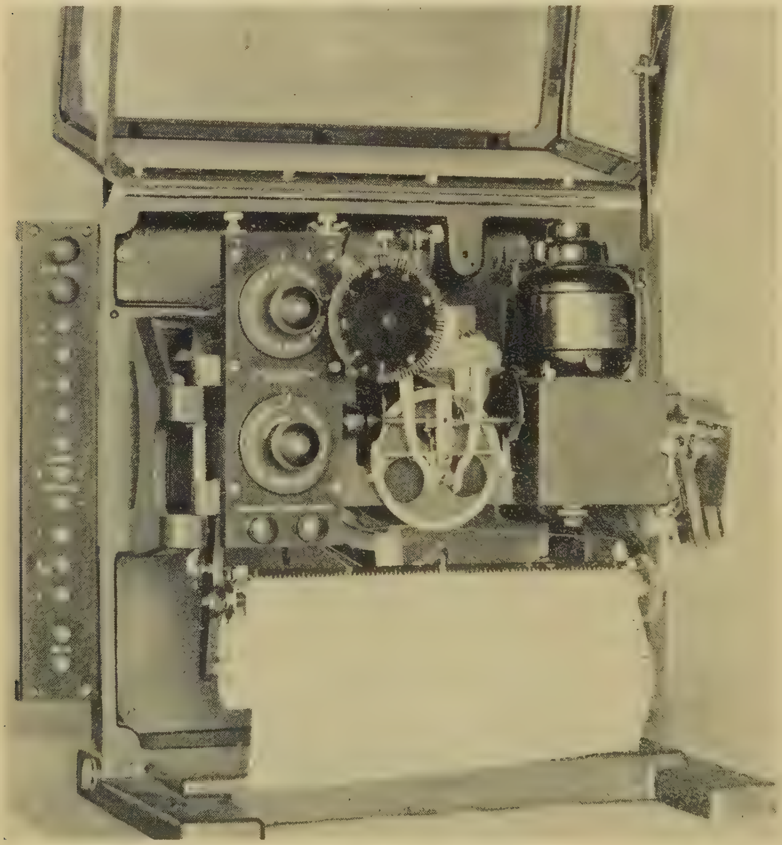

FIG. 6. RECORDING POTENTIOMETER

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[12] Parker and Greer, Preprint No. 2, April, 1926, Amer. Electrochemical Society.

can also be applied for measuring the pH of a flowing solution. The simplicity, ease of manipulation, freedom from "poisoning" and accuracy, make this electrode ideal for a large number of industrial applications.

RECORDING pH

In processes where a continuous record of the pH is desired, use is made of a recording potentiometer, figure 6. The titration curves of samples of boiler feed water with H_2SO_4, using such a recorder, are shown in figure 7. Curve A was obtained by adding H_2SO_4 at a constant rate to a sample from a boiler whose feed water had no pretreatment, curves B and C with boiler feed waters previously treated with caustic soda, and curve D with lime and soda treated feed water. The original pH of these samples were A = 9.65, B = 10.8, C = 11.6, and D = 11.9.

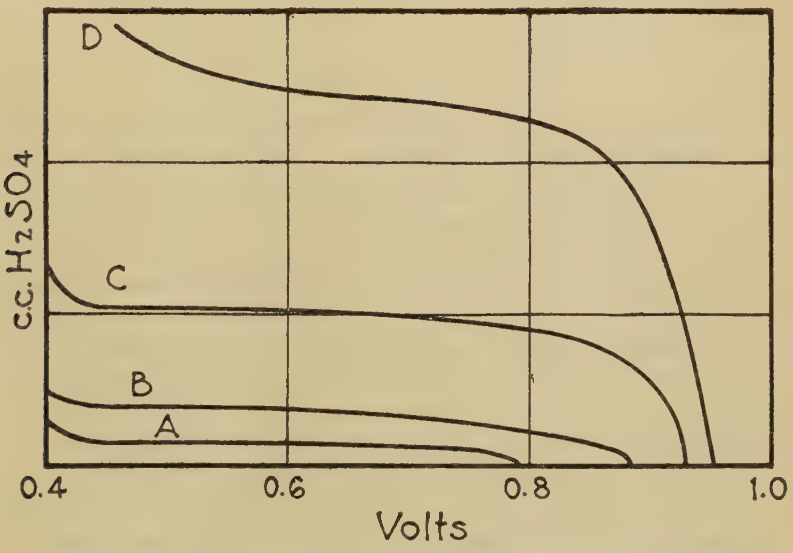

FIG. 7. TITRATION CURVES OF BOILER WATERS

The use of a recorder-controller potentiometer will be discussed in a subsequent paper on the automatic control of H-ion concentration of boiler feed water.

If the pH of boiler water is maintained at a value of 9 to 10, pH measurements will give an indication of an excess or deficiency of caustic. At higher pH values, however, the change in pH with increased causticity is too small to be of real value, as is indicated by curves C and D, where the difference in pH is only 0.3, whereas the difference in alkalinity is considerable.

Perhaps the most important use of pH measurements is in determining the proper treatment when first starting up a boiler. In such cases pH measurements give a much better indication of the amount of chemcal that should be added to compensate for hydrolyzable salts, than do alkalinity determinations. pH measurements will also indicate the building up of salts in the boiler, and may be used as a true indication of chemicals required if the pH does not exceed a value of 10.5

SUMMARY

1. "Alkalinity" measurements have long been used as a method of approximating H-ion concentrations. The presence of hydrolyzable salts introduces an error, the magnitude of which is such that the determinations are of value only for indicating the "available" acidity or causticity. Consequently, H-ion measurements are frequently of greater value in the control of boiler water or boiler feed water.

2. The determination of hardness by the "soap method" gives, at best, only approximate values, which are nearly independent of the pH.

3. There is a more or less definite relation between the "alkalinity" and pH of *natural* waters at the lower "alkalinities."

4. The use of the hydrogen, quinhydrone and tungsten electrodes has been described. The latter two can be used in a flowing solution to give a continuous record of pH.

AMOUNT OF WATER AVAILABLE FROM IMPOUNDING RESERVOIRS[1]

By H. L. White[2]

Many towns in southern Illinois, unless they are located on a large stream, find that the question of a satisfactory water supply is always staring them in the face. This is particularly true in the coal and oil fields. Wells in the mining regions furnish water that is unsuitable for a water supply because of high mineral content and disagreeable taste. As a result, towns in these districts have turned to the impounding reservoir as a solution to their problem. Within the last year or so Carbondale, Carthage, Sesser and West Frankfort have begun using water from impounding reservoirs.

Although many municipalities will be compelled to use surface water stored during times of heavy rainfall, few data on Illinois streams have been published to aid these towns in determining the size of reservoir and the drainage area required.

In order to supply this need, the State Water Survey Division has undertaken the task of collecting precipitation and runoff data. With the assistance of the City of Centralia, through L. W. Lemon, City Engineer, the Water Survey has begun the collection of data from the drainage area which supplies the Centralia impounding reservoir.

The amount of precipitation on the drainage area is measured in a standard rain gauge, the amount of water drawn from the reservoir each day by the city is metered, and the water level in the reservoir is to be recorded on a Stevens recording gauge. The water level is, at present, read once a day by the reader of the rain gauge. An abstract of the data collected is given in table 1.

The State Geological Survey Division, in coöperation with the United States Geological Survey, is assisting by determining the watershed which lies outside of the region for which a topographic map is now published. Within the region for which a topographic map has been published, the State Water Survey Division has located the watershed.

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[1] Presented before the Illinois Section meeting, January 27, 1927.

[2] Assistant Engineer, State Water Survey Division, Urbana, Ill.

H. E. Grosbach, Assistant Engineer, United States Geological Survey, has given information about water level recorders and offered to measure the amount of water which overflowed the spillway.

TABLE 1

Centralia Reservoir data

MONTH	RAINFALL DURING MONTH		WATER USED FROM RESERVOIR DURING MONTH, GALLONS	WATER LEVEL IN RESERVOIR, FEET	GAIN IN STORAGE, GALLONS
	Inches	Gallons on 7 square miles			
1925					
December				102.4±	
1926					
January	3.59	438,000,000	165,000,000	109.0	+306,000,000
February					
March	3.11	379,000,000	51,618,000	110.59	+98,000,000
April	5.04	614,700,000	38,119,500	114.42	+281,000,000
May	0.98	119,600,000	56,304,000	113.08	−107,000,000,
June	1.22	148,800,000	55,154,000	112.0	−79,000,000
July	3.42	417,100,000	65,903,000	110.75	−85,000,000
August	3.82	465,900,000	55,872,500	109.83	−58,000,000
September	8.10	987,900,000	53,288,000	113.18	+230,000,000
October	7.13	869,600,000	55,381,000	114.67	+119,000,000
November*	2.53	308,600,000	57,759,500	115.17	+42,000,000

Note: Table to be revised when actual drainage area is determined.
One inch rainfall from 7 square miles = 122,000,000 gallons.
* Overflowed spillway during month.

With the assistance of the City of West Frankfort, through E. A. Cox, City Engineer, the State Water Survey is collecting rainfall data for the West Frankfort impounding reservoir. The rain gauge is not located at present close enough to the center of the watershed.

It is hoped, that, in the future, engineers who have charge of the design and construction of storage reservoirs will make some provision for collecting precipitation and runoff data, since the expense is not great and the benefits to towns in this region are of considerable value.

DISCUSSION

J. J. Woltmann: I have been interested in runoff from Illinois streams for a long time and have been surprised at the meagre data available. Has there been any attempt to determine evaporation from the water surface at Centralia?

H. L. White: No.

G. C. Habermeyer: Evaporation experiments are so difficult to make unless the right kind of help is available that they have not been attempted at Centralia.

J. J. Woltmann: What account was taken of the spillway overflow?

G. C. Habermeyer: The spillway did not overflow in 3 years. Nearly all of the flood flows could be measured by the rise of water level in the reservoir.

PHENOL TASTES IN CHLORINATED WATER[1]

By L. C. Osborn[2]

The City of Loveland has been sterilizing its water supply for more than fifteen years. Until 1923 this had been accomplished by applying hypochlorite of lime in a rather hap-hazard manner, using a crude dosing apparatus that fed the solution into the transmission main at a uniform rate regardless of the rate of flow of the water. There was no measuring device to give the rate of flow and no storage to take up the peaks and valleys of consumption. The rate of dosage was controlled by bacteriological examinations taken once a week or perhaps once a month depending upon the season and the last result.

All this time there were intermittent complaints about taste in the water. The natural assumption was that the taste was the result of overdosage because of the unknown rate of flow and the fact that each new batch of hypo had a different amount of available chlorine. No thought was given to phenol tastes.

In 1923 the city began the construction of a modern filter plant providing excellent manual control chlorinating apparatus and a good water measuring device. During this construction period the water consumers suffered patiently with raw river water heavily impregnated with hypo, dreaming of the time when they would have the best water plant that money could buy.

Finally the big day came, especially for me. The Wallace & Tiernan man arrived on the job, set up the chlorinating apparatus, gave the operator instructions, turned on the gas and then took the next train out of town. The filter plant operator tore up the old hypo barrels and kept his eye on the water meter, hoping to deliver the real stuff. The customers knew nothing of the change, but the next morning the response was immediate and often profane. The taste was intolerable. A careful checkup on the chlorine apparatus showed that it had performed perfectly, delivering three pounds of gas per million gallons of water. This was cut down to two, and an ortho-tolidine outfit showed no free chlorine after thirty minutes of contact. However, the taste still persisted. In about three weeks it diminished and in a month it practically disappeared. In the meantime, I tumbled to the fact that at the same time the new chlorinator was put in operation, the city had also put into service a new 36-inch creosoted wood pipe line. This pipe, two miles in length was the feeder for the city's new hydro-electric project situated ten miles above the water works intake. The river flow at this time was 75 c.f.s. and probably about 10 c.f.s. flowed through the creosoted wood pipe. The proportion of creosote present in the river water must have been minute and was absolutely unnoticeable before the water was chlorinated. This was the writer's first experience with a phenol taste as such.

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[1] Presented before the Rocky Mountain Section meeting, February 7, 1927.

[2] City Engineer, Loveland, Colo.

Three months later another frightful taste developed over night. The filter plant operator reported everything O.K. and that gas was being applied at less than three pounds per miliion gallons of water. A careful checkup disclosed that the contractor, who was still working at the plant, had conceived the idea of brightening up the paint on the subway gratings by dipping them in a tar paint thinned with gasoline. After dipping they were placed on a shingle roof in the sun to dry, in an hour or so they were apparently dry and were replaced over the filters. The water entering the filters splashed just a little on a small portion of the grates. I cannot see how more than a half teaspoonful of this paint could have gotten into the water which was flowing at more than two million gallons daily. But there is no doubt that it caused the taste.

In September, 1924, the city's new transmission main from the filter to the city was put into operation. This line consists of eight miles of creosoted wood pipe, the upper four miles 20 inches in diameter, the lower four 24 inches in diameter. Before being put into service this main was flushed continuously for a period of about six weeks. As anticipated, a strong taste was noticeable. In fact, it was very disagreeable for about two months when complaints became less frequent. The remarkable feature of this period was that the taste was uniformly present in all sections of the city in spite of the fact that the old main was still in operation. All attempts at reducing the taste by dilution from the old main seemed futile.

In the latter part of December, 1924, a new storage equalization tank, of one and one-half million gallon capacity, located midway between the filter plant and the city, was put into service. A strong phenol taste again occurred. The tank is of concrete, but the connecting link to the pipe line is creosoted wood, and in spite of the fact that this pipe stood for several weeks full of water which was then changed and wasted three times, it was the cause of the taste.

When the tank was put into operation, the orifice meter at the filter plant became undependable on account of the fact that the pipe line was not always full. Consequently, determining the chlorine dosage became an estimating process until a weir was completed. During this period a phenol taste was present, the complaints indicating a varying intensity.

During the summer of 1925, the taste would disappear only to recur inexplicably. At the present, the same is true; however, let it be said that some individuals testify that a disagreeable taste is always present.

WATER SUPPLY AND STREAM DATA

The Loveland water supply is procured from the Big Thompson River. The drainage area is possibly 1000 square miles. The watershed is entirely mountainous, the normal stream consists of snow and spring water, very soft, cool and clear. The stream flow varies from 15 c.f.s. in winter to 2000 c.f.s. at early summer flood peak. The watershed is sparsely populated, having a permanent population of perhaps 500 persons; in the summertime the peak is possibly 20,000 persons. The only village is Estes Park. There is not a factory on the watershed and hence no problem of industrial waste. Estes Park sewage is treated before being emptied into the river. The City of Loveland patrols the watershed, attempting to prevent any nature of stream pollution. Bacteriological tests, however, nearly always indicate the presence of B. coli in the river water.

The source of phenol compounds causing the recurrence of chlorophenol tastes in Loveland's water is a matter of conjecture, but in my opinion may include the following: (*a*) motor wastes and washings from Estes Park garages; (*b*) chemical compounds contained in Estes Park sewage; (*c*) oils thrown off by decaying organic matter. The only indication of any such pollution is an oily appearance on the surface of the water in the river immediately below the city diversion dam. On account of irrigation diversions, it is only possible to see this during certain seasons.

PREVENTIVE MEASURES

No preventive has been discovered as far as the application of chlorine is concerned. The present policy is to use as small an amount as possible consistent with safe results. An attempt is made to maintain about 0.1 part per million residual chlorine. Daily bacteriological examinations are made to check results. The one attempt at superchlorination was disastrous from the taste standpoint

The only conclusions that I care to make are:

1. Loveland's raw water before being chlorinated does not taste.

2. Chlorine alone does not cause the water to taste, otherwise it would taste continuously.

3. It requires a ridiculously small amount of a phenol compound in chlorinated water to cause a taste.

Taking into account the source of many different complaints and taste examinations, the following statements seem to be reasonable, but are by no means conclusive.

1. The intensity of a chloro-phenol taste in water is greatest when the greatest time has elapsed since chlorination (within limits, of course). This is shown by

a. At no time has such a taste been detected in the chlorinated water at the filter plant

b. The taste seemed to be augmented by placing the storage tank in service

c. The taste seems to be more intense during a low period of consumption

d. The greatest complaint is from customers tapped on the larger pipe within the distribution system

e. The taste is greater in the morning while the water that has stood overnight is being consumed.

f. Farmer customers securing water from the city supply, when the same has a strong phenol taste, have stated that when stored in cisterns the taste is greatest after one week, when it gradually disappears.

2. Phenol tastes may be caused by the action of chlorinated water on sediment scale or coating in the pipe in the distribution system. This seems reasonable by complaints purely local in character and their nature causes the writer to suspect new cast iron mains.

Practically all Loveland water consumers know that chlorine is used as a sterilizing agent. I am of the opinion that tastes, real and imaginary, are magnified by this knowledge. The great difference of sense of taste in individuals and the close association of taste and odor make it difficult to tell whether the water is good or bad and what the cause may be?

SPORE BEARERS IN THE SPAVINAW WATER SUPPLY

By R. L. Ginter[1]

The Spavinaw Project was placed in service November 17, 1924. The 400-square-mile water-shed collects the water in a 20-billion gallon reservoir which is located approximately 65 miles to the east and north of Tulsa. From this reservoir the water flows to the Mohawk Pump Station where it is chlorinated, aerated and then pumped four miles to an inclosed high pressure reservoir located at the north end of the city

During the past few years considerable work has been done by various investigators on spore-bearing lactose splitting organisms which occur in water supplies. The water-works man is now aware of the limitation that must be placed on the interpretation of the standard presumptive test.

The descriptions of the various spore-bearing lactose fermenting organisms are omitted here. The reader is referred to the appended bibliography on the subject.

During the first month of the Spavinaw operation positive presumptive tests which did not confirm were obtained from water samples which had been treated with 0.4, 0.6 and 0.8 part per million chlorine. In all cases the gas production was more rapid in the chlorinated water fermentation tubes than it was in the untreated control water tubes. The trouble was apparently due to the presence of lactose splitting organisms other than Bacterium coli, for the laboratory record showed that the supply was not contaminated. The untreated water had a B. coli index of 0.1 per cubic centimeter and the average count on agar at 37°C. was 490. Throughout the year the B. coli index does not vary appreciably from the mean, whereas the count increases during the summer months and decreases through the winter season.

Positive presumptive tests were also obtained in the laboratory after chlorinating samples of the untreated water with various amounts of chlorine up to 2.0 parts per million. Again it was observed that the gas production on standard lactose broth was more rapid than it was on the control untreated water. This indicates that organisms in the untreated water which are killed by chlorine inhibit to a certain extent the microörganism in question. Prepared slides disclosed the presence of large Gram-negative oval organisms and, although these first cultures were not pure, the writer felt justified in reporting to the water department that the A. P. H. A. presumptive test was not indicative of the presence of Bacterium coli in the chlorinated water.

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[1] Chemist, Water Department, Tulsa, Oklahoma.

ISOLATION METHOD

Forty-eight hour positive lactose broth tubes were subcultured to Endo or eosin methylene blue agar plates. Transfers were made after forty-eight hours to a lactose broth tube and an agar slant by fishing from the edges of the growths on the Endo or eosin methylene blue agar plates. If gas was produced here on the lactose broth and the stained slide did not disclose Bacterium coli a transfer from this forty-eight hour agar slant was made to a third lactose broth tube which was then heated fifteen minutes in a water bath at 90°C., cooled and then incubated for forty-eight hours at 37°C. Agar plates were then streaked from the positive lactose broth tubes at this stage. Agar slants for study were then prepared by fishing from the edges of these forty-eight-hour agar plate growths. This method is essentially the same as that used by Norton and Weight.

MORPHOLOGIC AND CULTURAL CHARACTERISTICS

The organism is approximately twice the length of Bacterium coli and is oval in shape. Gram-negative cells occur singly, in pairs, but never in chains. The cells from forty-eight and seventy-two hour agar slants show a single spore, oval in shape and centrally located. Motility was observed in the majority of cultures. The attempts to grow this microörganism anaerobically failed. Indol tests were negative. The Voges Proskaur tests were positive and methyl red negative. All cultures studied liquefied gelatin after five days. Growths obtained on Endo and eosin methylene blue agar plates were not characteristic of Bacterium coli; on the former the growth was scant, somewhat branched and usually pink at the edges; and on the latter the growth was scant, light in color and branched. The metallic sheen produced by Bacterium coli on these media was entirely absent from growths of this organism on Endo and eosin methylene blue agar. Acid colonies were produced on purple lactose agar. Growth was not obtained in the Koser citrate solution.

Acid and gas in forty-eight hours were produced on lactose, sucrose, dextrose, mannite and starch. Fermentation results on dulcite and lactose bile were negative in ninety-six hours. Pure cultures of Bacterium coli isolated from human feces and water were used for control.

RESISTANCE TOWARD CHLORINE AND COPPER SULPHATE

An emulsion was prepared by looping the growth from a one-hundred-twenty-hour lactose agar slant to approximately 15 cc. of Dunham's peptone solution which was then introduced into 2000 cc. of sterile sodium chloride solution (8.5 grams per liter). The whole was well mixed and 200 cc. aliquots were then treated with various amounts of chlorine and copper sulphate. Each portion was shaken forty-five seconds, allowed to stand twenty minutes, and then tubed and plated. It was found that neither 17 parts per million chlorine nor 19 parts per million copper (in terms of metallic copper) killed this organism.

FREQUENCY OF ATYPICAL STRAINS

From 191 samples of chlorinated water collected from service taps, 41 per cent gave positive presumptive tests, 66 per cent of the positive presumptives did not confirm and 34 per cent confirmed. Thus atypical lactose splitting strains were present in 27 per cent of the total chlorinated samples collected. Ten pure cultures of this organism were isolated and studied, although all the atypical strains did not prove to be this oval Gram negative organism. In some cases complete failure of growth on Endo and eosin methylene blue agar was obtained and in other cases the procedure was dropped if gas was not produced on the lactose broth tube (subculture from Endo).

MEDIA USED

All agars were obtained from Digestive Ferments Company. The carbohydrates with the exception of the starch were obtained from the same company. The gelatin and ox gall were Digestive Ferments Company products. The sugar broths were adjusted to pH 7.2 to 7.5. The Koser citrate solution was made from C. P. Chemicals. The peptones were obtained from Digestive Ferments Company.

CONCLUSIONS

1. The organism studied is very similar to the one described by Norton and Weight.

2. No sanitary significance is attached to this organism for other workers have disclosed some evidence that the soil is at least a

secondary source of organisms similar to the one described in this paper.

3. Evidence that 5 per cent bile inhibits Bacterium coli has not been obtained.

4. It is not suggested here that the Standard sanitary water methods should be made more severe or more lenient. A change in the presumptive test, however, involving the use of a low per cent bile medium similar to that used by Dunham, McCrady and Jordan, would result in a saving of routine time. Such a change would also increase the dependence the water-works man places on the presumptive test.

ACKNOWLEDGMENTS

Appreciation is here expressed for the kind assistance of J. J. Weight, School of Medicine, University of Utah, in examining two of the cultures.

Appreciation is further expressed for the coöperation of water department officials.

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REPORT OF STANDARDIZATION COUNCIL

During the past year activities under the Council have related largely to the work of the committees on Standard Methods of Water Analysis and of Boiler Feed Water Studies; and to the appointment of two new committees on Standpipes and Water Towers and on Steel Pipes. These new committees were appointed following an investigation and report by special committees on plan and scope as well as general desirability of appointing such committees on the respective topics.

COMMITTEE ON STANDPIPES AND WATER TOWERS

A special committee consisting of J. E. Gibson, Chairman, Nicholas S. Hill, Jr., George H. Fenkell, H. F. Huy and Robert E. McDonnell recommended that a committee be appointed to prepare a standard form of specifications covering steel standpipes and water towers on a comprehensive basis and in December, 1926, the following committee was appointed:

James E. Gibson, Chairman, General Manager, Water Department, Charleston, S. C.
C. D. Abbott, Associated Factory Mutual Fire Insurance Company, Boston
James H. Edwards, American Bridge Company, New York City
George P. Horton, Chicago Bridge & Iron Works, New York City
L. R. Howson, Alvord, Burdick & Howson, Chicago
H. F. Huy, General Manager, Western New York Water Company, Buffalo
J. O'Leary, Pittsburgh-Des Moines Steel Company, New York City

STEEL PIPE COMMITTEE

The special committee appointed at Buffalo to deal with the steel pipe situation, consisting of Allen Hazen, George H. Fenkell, Clinton L. Bogert, Thomas H. Wiggin and Frank A. Barbour, Chairman, recommended the appointment of a committee to deal with this subject particularly as related to the following:

1. The collating of all existing information in reference to steel pipe lines now in use.

2. The selection of certain pipe lines as best available for further testing, with due regard to the desirability of wide geographical distribution and the representation of as many variations as practicable in the character of water carried.

3. The establishment of a standard method of testing for hydraulic losses with suitable variation for different conditions.

4. The selection for each pipe line of some group of engineers—perhaps a Section of the American Water Works Association—which can best undertake the testing of a particular line or lines under the general supervision of the Committee.

5. If, in order to carry on the tests, it is necessary to develop a field party, or a traveling supervisor of tests, the making up of a budget of the probable expense and ascertaining whether the manufacturers are willing to support the investigation to this extent.

6. Periodical reports to the Association of the results obtained.

In March, 1927, the following committee on steel pipe lines was appointed:

J. Waldo Smith, Board of Water Supply, New York City
Clinton L. Bogert, Consulting Engineer, New York City
George H. Fenkell, General Manager, Water Department, Detroit, Mich.
H. Seaver Jones, East Jersey Pipe Company, New York City
George W. Pracy, Spring Valley Water Company, San Francisco
Fred C. Scobey, General Irrigation Engineer, U. S. Department of Agriculture, Berkeley, Cal.
Frank N. Speller, Metallurgical Engineer, National Tube Company, Pittsburgh, Pa.
E. E. Wall, Consulting Engineer, St. Louis, Mo.
Charles V. Witt, Witt Steel Company, Greenburg, Pa.

STANDARD METHODS OF WATER ANALYSIS

Chairman Hinman reports that during the past year this committee has devoted the greatest amount of attention to the following topics:

1. The use of brilliant green lactose bile medium as a secondary fermentation test in the detection of organisms of the colon group. The idea in using this procedure is to make easier and speedier the detection of organisms of this group and their partial confirmation in laboratories which are not supplied with highly trained assistants.

2. The detection of phenols, which are so annoying in connection with taste development following chlorination.

3. The determination of iodine, which has received so much attention in connection with goiter surveys.

4. Further studies on the ortho-tolidine and soap tests for free chlorine and hardness of water respectively.
5. Studies on microscopic examinations of water with the use of the Foerst centrifuge.

Plans have also been developed for cooperating with the Committee on Boiler Feed Water Studies, particularly as related to the determination of dissolved oxygen and free carbon dioxide.

Further investigations have also been made of the periodate method for manganese and free chlorine determination, as well as additional studies on alkalinity and hydrogen ion concentration correlation.

BOILER FEED WATER STUDIES

Substantial progress has been made at the four meetings of the Executive Committee directing this undertaking and comprising representatives of the following organizations which are now officially sponsoring this movement:

American Water Works Association
American Society of Mechanical Engineers
American Railway Engineering Association
American Boiler Manufacturers Association
National Electric Light Association
American Society of Testing Materials

Progress reports of the nine sub-committees were presented at the December, 1926, meeting of the American Society of Mechanical Engineers in New York and the reports in part or in full have appeared in Mechanical Engineering, Railway Age and in the Journal of the American Water Works Association. Current monthly bibliographies have been prepared through the cooperation of Sub-committee 9 and the Publication Committee of the American Society of Mechanical Engineers. This material is being published in the journals of the associated engineering societies.

On June 8 at the convention of The Association in Chicago, an all-day session will be devoted to activities related to the work of this committee which is progressing at an increased rate, so that a full-time stenographer seems necessary in the early future in order to carry forward the work successfully. Contributions of $300 for the needs of this committee have been arranged for with several of the sponsor organizations.

At a meeting of the Executive Committee in December, 1926, it was found to be the consensus of opinion that the undertaking warranted appropriation for the establishment of a series of paid research studies at several universities equipped for such work. A Finance Committee has been appointed consisting of the following:

F. N. Speller, Metallurgical Engineer of the National Tube Company
C. R. Knowles, Superintendent of Water Service of the Illinois Central Railroad
A. J. Authenreith, Vice-President of the Middle West Utilities Company
A. E. White, Director of Department of Engineering Research, University of Michigan
J. B. Romer, Chief Chemist of The Babcock and Wilcox Company
S. T. Powell, Consulting Chemist, Chairman

Increasing interest is being manifested in the work of the committee on Boiler Feed Water Studies. Its reports have been widely circulated and demands for them have been received by its chairman from all sections of the country.

ABSTRACTS IN THE JOURNAL

Some difference of opinion is found among the members of the Association as to the advisability of continuing the abstracts as now appearing in the Journal. They are highly appreciated by some, but there seems to be others who prefer to see the space in the Journal occupied in other ways. The Council will have to decide at the Chicago convention whether these abstracts are to be continued at an expense which will be somewhat greater in the future than hitherto or whether the prevailing view of the Association would be for the discontinuance of this activity which was started under the direction of the Council in 1922.

Council will welcome assistance in the determination of this question and it desires to have this subject voted upon separately when this report is presented at the convention.

STATUS OF MANUAL OF WATERWORKS PRACTICE

The first printing of the Manual with an edition of 2500 copies was exhausted at the end of September, 1926, one year after its first appearance. A second printing of 1579 copies was made during October last and on April 15, 1927, 505 of them had been sold.

The Council has not been able to form a definite opinion as to the wishes of the membership concerning a revised edition, as compared with additional reprintings of the first edition. Some members think that the usefulness of the Manual will be enhanced if effort is limited to directing attention to it among the water works industry so as to increase its use among various workers, particularly members of water boards, superintendents and operating men. Others think that it would be helpful to rewrite portions of the Manual for the purpose of bringing the material more nearly up to date and condensing it to a substantial degree.

The Council desires to secure an adequate record of what the membership desires and to this end proposes to request the Secretary of the Association to write promptly to the chairman of each geographical section, of each national division and of the Manufacturers Association, inviting each to send a delegate to a conference which the Standardization Council proposes to hold at 4:30 p.m. on Monday, June 6, at the Chicago convention to develop a plan for ascertaining the wishes of the membership as to the future of the Manual.

The activities of the Council during a period of 5 years in securing material for the book in its present form have led some to believe that it would be wise to leave matters in abeyance until the membership voluntarily indicated its desires as to procedure. On the other hand, it is pointed out that what the members really think about the Manual is not likely to come to the front, unless there is some canvassing agency set up to ascertain systematically what the wishes are of the membership, not only as it assembles at its annual conventions, but as its members gather at various meetings of the sections throughout the country.

Council does not propose to be hurried in taking any steps as to revision of the Manual, but will welcome comments from all sources and will be glad to have the benefit of them at the conference in Chicago when, with the aid of the delegates from the different sections and divisions, it is hoped that there may be set up an active representative canvassing committee which will bring from all groups helpful information to the Council for its consideration in the premises.

Frank A. Barbour,
W. S. Cramer,
W. W. DeBerard,
E. E. Wall,
George W. Fuller,
Chairman.
Malcolm Pirnie,
Secretary.

DISCUSSION

SPECIFICATIONS FOR CAST IRON PIPE

In discussion on page 755 of the December, 1926, JOURNAL, J. N. Chester briefly recommends four "classes" for 12-inch water mains. These are supposed to meet the requirements for pressures, heads, etc., established by or credited to The American Water Works Association many years ago. The subject of "classes" is not altogether new, or at least new to the JOURNAL. Several years have passed since that particular size, 12-inch, was subjected to examination and review[1] with respect to classes under conditions somewhat carefully set forth. Would it be unreasonable to beg the author to look over that earlier discussion, criticise it deservedly, assign it to a proper place, or give it his besought approval?

At that time I stated, among other things:

> In these brief notes let only one size (12-inch) and but one quality of iron (tensile strength, 18,000 pounds) be considered. For 12-inch inside diameter pipe, "Class A" shows a factor of safety of 37 against bursting pressures. But for the risk in handling the pipes that factor might safely be less than half as great. "Class B" shows a factor of safety of 21 for the specified head of 200 feet. It is fairly evident that if a pipe can be transported and safely laid where the head is to be 100 feet the same pipe can be transported and safely laid where the head is 200 feet. It is also clear that if we could discover an American Water Works Association authority for using 12-inch pipes under a factor of safety of 18 instead of 21, "Class A" pipe could be substituted for "Class B," and "Class B" would go out altogether. That would be a marked advantage.
>
> Skipping over one class for a moment, consider "Class D" for a head of 400 feet. Transportation and laying do not call for special increments in "Class D" pipes. The factor of safety for "Class D" is 13. Now it may be said that if a factor of safety of 13 is suitable for 400 feet head, a factor of safety of 18 is proper for 200 feet head, and "Class B" does go out. There is still another class, "Class C." If "Class A" pipe be substituted for "Class C" pipe, the factor of safety with 300 feet head would be 12.46. It might with general consent be said that if a head of 400 feet demanded a factor of safety of 13, a distribution system under 300 feet head would be reasonably secure with a factor of safety of 12.46. Then there would be two classes instead of four classes. "Class A" for pressure up to 300 feet and "Class B," as the present

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[1] JOURNAL, 7, 1920, pages 366 and 765.

"Class D" would then be called, for service up to heads of 400 feet, and except for the thickened walls to prevent breakage in laying "Class A" the factor of safety would be fairly uniform throughout. Besides this conforms to average experience. No one would hesitate to lay a main under a head of 300 feet when assured that the factor of safety was twelve, that the metal was of good quality and that the pipe had been thoroughly tested under a pressure of 300 pounds to the square inch."

Interest attaches to estimates and notations of the years or decades that must elapse before the American Water Works Association shall avail itself of the merit and advantages incident to the use of factors of safety in its designs and specifications for cast iron water pipe and special castings.

H. F. DUNHAM.[2]

[2] Civil Engineer, New York, N. Y.

A MODEL BOND LAW

Editorial Comment

The incurrence of indebtedness by municipalities and other political subdivisions of the state has been the subject of almost as many varieties of legislative practice as there are municipalities. The financing of public improvement projects through the issuance of long term securities is in many states restricted in minute degree, although not always in accord either with administrative wisdom or sound financial practice, while in other states it is subject to no restrictions. In these latter groups, the procedure in the incurrence and subsequent payment of debts for municipal projects is subject to the vagaries of lay and professional individuals, in many instances unfamiliar either with the theory or the practice of municipal finances.

It is all the more gratifying, therefore, that the National Municipal League of New York City has recently submitted, through its committee on Municipal Borrowings, a draft of a Model Bond Law. This draft is the result of over five years of deliberations on the part of a committee representing financial, legal, legislative and administrative groups. The text of this model act represents the consensus of opinion of this group of experts, as to the purposes for which political entities may be authorized to borrow money; as to the term and type of bonds to be issued for such purposes; and as to the provisions which should be made for sale and for retirement. Such a statewide bond law is proposed in order to bring all localities to somewhere nearly a uniform standard practice.

Although the proposed act contains no particularly novel features, it offers a guide to public officials who may be interested in accepting the lessons of experience and in eliminating the existing statutes which place municipalities at a disadvantage in the bond market. This suggestion of the committee for uniform and simplified practice is well worth the attention of the reader.

Although there are some items in the proposed act upon which the experts could not agree, there are sufficient suggestive features therein to be helpful to any who are concerned with the incurrence of municipal indebtedness. The disagreement of the committee is particularly emphasized in the minority report on the issuance of sinking fund bonds. The majority of the committee goes strongly on record for the issuance of only serial bonds, whereas a minority of the committee believes that "large cities with sound financial traditions should still be empowered to issue sinking fund bonds." There is considerable strength in the statement of the majority that sinking fund bonds have frequently been misused by administrators. There is room, however, for discussion as to whether such bonds should be prohibited by state law in the case of such municipalities which have ample protection against defective and dishonest public administration.

Among other things the model law permits the issuance of bonds only for permanent improvements. Bonds to meet current expenses are forbidden. Included in the act are schedules for the probable life of the property or improvement to be carried out. These schedules are intended to regulate the terms of the bonds.

Another provision, the lack of which has hampered many public expenditures, is that permitting municipalities to sell bonds at less than par, but not less than 95 per cent of par.

Those familiar with the inconsistencies and inadequacies of many municipal improvement enabling acts should receive with considerable interest the model bond law proposed, or some equivalent.

ABEL WOLMAN.[1]

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[1] Editor, Journal of the American Water Works Association; Chief Engineer, Maryland Department of Health.

SOCIETY AFFAIRS

KENTUCKY-TENNESSEE SECTION

The second annual meeting of the Kentucky-Tennessee Section convened at the Hotel Peabody, Memphis, Tennessee, on January 19, 1927, with C. E. Davis presiding as Chairman.

In the absence of the Hon. Rowlett Paine, Mayor of Memphis, Vice Mayor T. H. Allen, who is also a consulting engineer, gave the address of welcome. W. S. Cramer, Past President of the American Water Works Association, responded.

The report of the Secretary-Treasurer for the year 1926 was given and it was moved and seconded that the report be accepted.

Topical discussion on the "Method of acquainting the public with its water supply" was opened by F. W. Albert and was participated in by W. S. Patton, W. S. Cramer, and James Sheahan.

Discussion on the "Psychological effect of water works buildings and grounds upon the public in its attitude toward the purity of the supply" was opened by L. S. Vance and was participated in by H. R. Fullerton, R. J. Morton, F. W. Albert, W. S. Patton and W. W. Mathews.

Discussion on "Are valves necessary on all fire hydrant branches and are hydrants used for any purposes other than by the fire department" was opened by E. T. Holman and participated in by F. W. Albert, T. H. Allen, T. H. Gothard, W. S. Cramer and W. G. Stromquist.

Chairman Davis appointed L. S. Vance and G. T. Bogard representing Kentucky and H. R. Fullerton and E. T. Holman representing Tennessee as Nominating Committee. This committee was instructed to report at the afternoon session.

W. G. Stromquist and Albert Clemens were appointed the Committee on Resolutions.

The meeting then adjourned until 1:30 p.m.

A paper on "Relation of Water Supplies to the Public Health" by Dr. E. L. Bishop, Commissioner of Public Health of Tennessee was read by R. J. Morton as Dr. Bishop was unable to be present.

Dr. Bishop's paper was thoroughly enjoyed by all present for it gave many of them a new insight into what the State Health Department of Tennessee is trying to do to improve the water supplies in the state. The paper was discussed by W. S. Cramer, W. S. Patton, F. W. Albert, F. C. Dugan and W. A. Patton.

Col. F. W. Albert, then spoke on "The New Knoxville Water Plant" and illustrated his talk with lantern slides. His talk was extremely interesting in showing the many problems which have to be studied and solved before proceeding with construction of a plant. Many questions were asked by the members as to how various problems had been solved.

The Nominating Committee then reported as follows:

Officers and Directors for 1927; Chairman, W. S. Patton; Vice Chairman, F. W. Allen; Directors, W. H. Lovejoy and S. R. Blakeman.

It was moved and seconded that the Committee's report be accepted and the above constitute the officers and directors for the coming year.

Topical discussions were called for.

Discussion was opened on "What methods are used for following up those hydrants so used that proper inspection may be made on them" by T. H. Allen and participated in by T. H. Gothard, L. S. Vance, F. W. Albert and W. S. Cramer.

Discussion was opened on "Do you maintain close co-operation with the fire department" by W. S. Patton and participated in by T. H. Gothard, James Sheahan and E. T. Holman.

Discussion was opened on "Has there been a campaign inaugurated in your city for fire prevention and are you taking part in this work" by W. S. Cramer and participated in by W. G. Stromquist, E. T. Holman, T. H. Allen, C. N. Harrub, W. S. Patton and Albert Clemens.

The meeting then adjourned until 9:30, January 20.

The meeting was called to order by Chairman Davis at 9:30 a.m. January 20.

"Stream Pollution in Relation to Water Supplies" was the title of the paper read by C. N. Harrub. The paper was discussed in considerable detail by F. A. Mantel, F. W. Albert, F. C. Dugan, A. P. Learned and H. R. Fullerton. A resolution relating to the pollution of streams was offered by Mr. Harrub for action. This was referred to the Committee on Resolutions.

"The Water Supply Problems of Tennessee" was the title of the paper read by H. R. Fullerton.

"Chlorination of Water Supplies" by G. R. Kavanagh was then read.

Discussion was opened on "What size connection should be allowed for private fire protection and should such services be metered" by E. T. Holman and participated in by W. S. Patton, F. W. Albert, James Sheahan, Albert Clemens, W. W. Mathews, and W. A. Patton.

C. R. Knowles, spoke for a short time on the plans of the meeting of the American Water Works Association at Chicago in June and urged every one to attend.

The meeting then adjourned until 1:30 p.m.

W. G. Kirchoffer read a paper on the "Analyses and Tests for Capacity of Water Supplies from Sand and Gravel Formation." This paper was a most instructive one and was discussed in considerable detail by T. H. Allen, A. P. Learned, R. J. Morton and C. E. Davis.

A motion picture entitled "The Modern Moses" was shown by the representatives of the Layne and Bowler Manufacturing Company, Memphis, Tennessee.

"Mosquito Control Measures for Impounded Water Projects" was given by J. A. LePrince, Senior Sanitary Engineer of the United States Public Health Service. This paper was extremely interesting and contained information of much value, especially to those who had impounded water supplies. The discussion was participated in by C. N. Harrub, W. W. Mathews, W. G. Stromquist, F. W. Albert, R. J. Morton, A. P. Learned, H. R. Fullerton, G. T. Bogard and W. L. Webster.

Discussion was then opened on "What is an adequate rate for automatic sprinkler systems" by W. S. Patton and participated in by W. W. Mathews, G. H. Parker, W. S. Patton, F. W. Albert, Albert Clemens, John Callery, J. H. Swope and W. S. Cramer.

The meeting then adjourned until 9:30 a.m., January 21.

The Section was entertained that night by the members of the Board of Water Commissioners, F. G. Proutt, W. J. Mallery, and W. W. Dean. A dialogue by the twin granddaughters of Mr. James Sheahan, a wrestling bout, and interpretative dancing added much to the enjoyment of the occasion.

The meeting was called to order by Chairman Davis at 9:30 a.m., January 21.

James Sheahan read a paper entitled, "The Construction and Operation of the New Memphis Water Plant." Discussion of this paper was participated in by C. Edwards, F. G. Proutt, A. P. Learned, F. W. Allen, W. S. Patton, C. N. Harrub, J. O. Sallee, W. S. Cramer and T. H. Gothard.

G. H. Parker then opened discussion on the "Standardizing of hose connections." T. H. Gothard, W. H. Cramer and E. T. Holman added to the discussion.

It was then moved and seconded that a limit of ten minutes be placed on all subjects brought up for discussion.

"Scientific Rate Making, How is it Done?" was discussed by F. W. Albert and F. G Proutt.

A. E. Clark opened a discussion on "What is the minimum amount of laboratory work necessary for the smaller plants of Kentucky and Tennessee, and what is the cost of such work, and how can it be handled by the regular operator." It was participated in by C. S. Layson, Jr., T. H. Parker and W. S. Patton.

Discussion was opened on "How often are complete valve inspections made of entire distribution system" by James Sheahan and was participated in by T. H. Gothard, W. S. Cramer, F. W. Albert, F. G. Proutt and L. S. Vance.

W. S. Patton, Chairman for 1927, announced that the meeting place for the third annual meeting would probably be at Louisville, Kentucky and the Committee on Arrangements for the meeting would be W. S. Cramer, Chairman, George C. Bogard and L. S. Vance.

It was announced that the appointment of the Secretary-Treasurer would be made after the meeting of the Executive Committee.

The meeting then adjourned until 1:30 p.m., when the members were taken on an inspection trip through the Memphis Water Works and a trip through the city parks.

The Executive Committee reelected F. C. Dugan as Secretary-Treasurer.

Resolutions were adopted extending a vote of thanks to Vice-Mayor Thomas J. Allen and to James Sheahan for their important part in making the meetings a success; to the Hotel Peabody for courteous hospitality; to the water commissioners of Memphis, F. G. Proutt, J. M. Dean and W. M. Mallory, for providing entertainment facilities; to W. J. Kirchoffer and J. A. Le Prince for the courtesy of presenting two papers of valuable character. The following resolution was also passed.

WHEREAS: The protection of the waters of the state against such pollution as will render them unfit for use as sources of domestic water supply, is, of vital importance to water works men and engineers, and,

WHEREAS: The increasing industrial activity and construction of sanitary sewerage systems, unless adequately controlled, will tend to render these waters unfit as sources of domestic water supply, and,

WHEREAS: The control of the pollution of these waters is a sanitary engineering problem which can best be administered through the Division of Sanitary Engineering of the Health Department of the State,

Be It Resolved: That it is the consensus of opinion of the Kentucky-Tennessee Section of the American Water Works Association that the State Department of Health should be provided with sufficient funds to employ the necessary sanitary engineers and laboratory personnel to enable them the make thorough sanitary surveys of all streams now used, or of potential value as sources of public and quasi-public water supply.

Be It Further Resolved: That copies of this resolution be sent to the State Departments of Health and to the members of the Legislatures of Tennessee and Kentucky.

F. C. DUGAN,
Secretary-Treasurer.

ROCKY MOUNTAIN SECTION

Twenty-six members and sixty visitors attended the first annual meeting of the Rocky Mountain Section, held in Denver, February 7 and 8, 1927. A full and well balanaced program of addresses, technical papers, motion pictures, round table discussions, section business and inspection trips proved interesting and valuable to all who were present.

The Section was exceedingly fortunate in having such capable and well qualified speakers on this program. Among those of national prominence were Beekman C. Little, Secretary of the Parent Association; Samuel A. Greeley and Wm. M. Barr. L. H. Enslow and Wynkoop Kiersted prepared excellent papers which were read at the meeting in the absence of their authors.

In addition to the papers scheduled on the program, one entitled "Orifice Type Meters," illustrated by lantern slides, was delivered at the Tuesday morning session by G. D. Conlee.

At the business session the election of officers and directors resulted as follows: Chairman, Paul E. Strouse, succeeding himself; Vice Chairman, L. C. Osborn, succeeding A. W. Stedman; Secretary-Treasurer, Dana E. Kepner succeeding himself; Directors, terms ending 1930, A. W. Stedman and E. A. Lawver, succeeding

W. S. Rathbun and D. P. Porter respectively. A motion to have a program Committee appointed by the Chairman to arrange for the 1928 meeting was duly passed, and on it were appointed R. S. Sumner, A. D. Mars, Jr. and Prof. C. F. Poe. Motions were also passed directing the Chairman to appoint an editor and a committee to consider a cooperative arrangement between the Section and the Colorado Municipal League. The editor has not yet been appointed, but the Committee on Cooperation consists of P. S. Fox, D. E. Kepner and P. E. Strouse.

After the advantages of membership in Colorado Engineering Council had been mentioned, the Section voted to apply, designating Dana E. Kepner as its representative in case the application is favorably acted upon. Membership in the Council permits a close cooperation between the local engineering societies and provides that each individual member of the various member societies will receive the monthly Engineer's Bulletin.

A resolution was adopted favoring the passage of Senate Bill No. 346, pertaining to the Division of Sanitary Engineering of the Colorado State Board of Health, with two amendments, one striking out that part which transfers the laboratory work from the Division to the State Bacteriologist, and the other providing that vouchers for expenditures of the Division be approved by the Director and by the President or Secretary of the State Board of Health. Another resolution, declaring it to be the opinion of the Section that the Governor should appoint two engineers on the Colorado State Board of Health, was also adopted.

The program follows:

MONDAY, FEBRUARY 7

Morning Session

Address of Welcome on behalf of the City of Denver. Hon. Benjamin C. Stapleton, Mayor of Denver.
Response on behalf of the Section. Chairman Paul E. Strouse.
Water Supplies for Automatic Sprinkler Protection. Karl Eppich.
Phenol Tastes in Chlorinated Water. L. C. Osborn.
Greetings from the Parent Association and from other Sections. Beekman C. Little.

Afternoon Session

Well Water Problems. Paul S. Fox.
Practical Utility of Bacteriologic Control of Water Supplies. Ivan C. Hall.
Methods and Costs of Water Softening. Wm. M. Barr.

Sewage Treatment and Disposal. Samuel A. Greeley.
Should Apparently Safe Water Supplies be Chlorinated? L. H. Enslow.

Dinner Session

Motion Picture, "Your Glass of Water—Are You Sure It is Safe?" Pennsylvania State Department of Halth.
Motion Picture, "A Modern Sewage Treatment Plant." Portland Cement Association.
Discussion—Water Works Legislation in the Rocky Mountain States. Led by D. E. Kepner.

TUESDAY, FEBRUARY 8

Morning Session

The New Mechanical Filter Plant at Ft. Collins, Colo. Wynkoop Kiersted.
Round Table Discussions:
  Slush Ice Control, led by A. W. Stedman.
  Industrial Wastes, led by D. P. Porter.

Afternoon Session

Trip to Marston Lake Filter Plant, Denver. Courtesy of the Denver Municipal Water Works, R. S. Sumner, General Manager.

WEDNESDAY, FEBRUARY 9

The City of Ft. Collins, Colorado gave an inspection trip to the new Filter Plant in the Poudre Canon.

D. E. Kepner,
Secretary-Treasurer.

ILLINOIS SECTION

The annual meeting was held at the Abraham Lincoln Hotel in Springfield, January 27 and 28, 1927. The first day was a joint meeting with the Water Works Section of the Illinois Society of Engineers. The total registration was 102, classified as follows: 30 active members of the Illinois Section, 3 active members from other sections, 18 representatives of associate members and 2 representatives of cooperative members.

The program given below was carried out.

THURSDAY, JANUARY 27, 1927

Morning Session

Joint Meeting with Illinois Society of Engineers, L. R. Howson, Chicago, Chairman

Wells in Buried River Valley at Sullivan, Illinois. W. D. P. Warren.
Improvements in Lime Softening Methods at Columbus, Ohio. Chas. P. Hoover.

Water Works Improvement at Streator. F. G. Gordon.
Coördination of Sewage Disposal and Water Purification. Paul Hansen.
The Springfield Water Softening and Treatment Plant. C. S. Timanus.
The Operation of the Springfield Water Purification Plant. C. H. Spaulding.

Afternoon

Excursions under guidance of W. B. Walraven and Frank Sheets, to the water purification plant, sewer construction, sewage pumping stations under construction and in operation, mining of shale, making of brick, Lincoln's Home and Lincoln's Tomb.

Evening

Annual Dinner

Election of Officers.
Address by John Gamber, State Fire Marshal.
The 1927 Convention of the American Water Works Association at Chicago in June, 1927. F. G. Merkle.

FRIDAY, JANUARY 28, 1927

Morning Session

Preliminary Experiments on the Treatment of Lake Michigan Water for Chicago. John R. Baylis.
Water Purification Development at Indianapolis. Harry E. Jordan.
The Iron Removal Plant at Champaign. Frank C. Amsbary, Jr.
Summary on Alum Coagulation. A. M. Buswell.

1:30 p.m.

The Cause and Prevention of Embrittlement of Boiler Plate. Samuel W. Parr and F. G. Straub.
Riverside Water Works. Chas. E. De Leuw.
Methods of Financing Water Works. George Blanchard. Read by Henry Ringness.
Discussion of Financial Problems, led by W. R. Gelston.
Amount of Water Available from Impounding Reservoirs. H. L. White.

The annual business meeting was held after the annual dinner at the Hotel Abraham Lincoln, January 27, 1927. The following officers were elected for the ensuing year: G. C. Habermeyer, Chairman; C. M. Roos, Vice-Chairman; H. E. Keeler, Treasurer, and W. R. Gelston, Trustee (to 1930).

The following resolution was presented by Harry F. Ferguson and was adopted:

WHEREAS: The proper treatment and disposal of sewage and trade wastes is of vital interest in many cases to waterworks men in order that our present and future water supplies may be protected from objectionable pollution, and

Whereas: There is now no division of the American Water Works Association established to give consideration to this matter,

Be It Resolved: That the Illinois Section recommends to the American Water Works Association that there be established in the parent association a Division on Sewage and Trade Wastes Treatment and Disposal in so far as such affect or may affect water supplies for domestic or industrial uses, and

Be It Further Resolved: That if Division is established that the Division coöperate in this work with the Sanitary Engineering Section of the American Society of Civil Engineers, the American Public Health Association, and other similar agencies in order that the greatest progress may be made and duplication of effort avoided.

After the business meeting John Gamber, State Fire Marshal, spoke on Fire Prevention.

M. L. Enger,
Secretary.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Well Water. F. W. G. Clark. Pekin and Tientsin Times. British Municipal Council's scheme of a deep well system for Tientsin is first of its kind in the Far East. First well bored to depth of 460-feet has produced 300,000 gallons daily. The success of this well has caused the Council to decide to bore five more wells. The program of development calls for three complete stations of a standardized similarity, each with a normal capacity of half million gallons daily. During the summer the maximum water demands have risen above a million gallons a day. The concession's first water supply system established in 1899 consisted of pumping water from the river, a somewhat undesirable source. Previous to this date all water used had to be hand-drawn in buckets at the banks of the river.—*A. W. Blohm.*

Cutting Metals Under Water. L. F. Hagglund. Paper presented at International Acetylene Association Convention, November 12, 1926. The method developed for cutting metal under water by means of the use of a jet of oxygen upon metal heated by the electric arc is described. The apparatus which permits the cutting of any metal at any divable depth, consists of a generating unit, switchboard and resistance, a supply of oxygen, oxygen gauge and hose, and double conductor hose through which both oxygen and electricity are carried to the torch.—*A. W. Blohm.*

Protective Coatings. E. M. Converse. Paper at Mid-Continent Section, A. S. M. E., December 9, 1926. Cost of corrosion in oil equipment investment of the country is estimated at many millions of dollars annually, indicating that protective coatings at present in general use are not functioning to a satisfactory degree, or they are not used as extensively as the case demands. Following characteristics desirable for an efficient protective coating: Both chemical and mechanical protection should be provided; material should not be affected by underground or atmospheric conditions; it should penetrate to seat of corrosion; the vehicle should permit functioning of inhibitor; protective coating should remain in form of an elastic non-drying film to give long time protection; it must permit of practical application.—*A. W. Blohm.*

The Utilization of Water Power in the Czechoslovak Republic. Joseph Wolf. Ministry of Public Works, 1926. Construction of hydro-electric stations in the Czechoslovak Republic is closely combined with systematic electrification of the state. Water-power resources which could be of importance for electrification are being developed by the state, the state and province, the province and by companies. Twelve electric stations, supported by the state, put into operation at the time of the birth of the Republic, are producing 23,360 horsepower. Work has been started on 10 other hydroelectric power plants with total capacity of 200,960 horsepower.—*A. W. Blohm.*

Report on the Working of the Corporation Water Analysis Laboratory, Madras. Corporation of Madras, 1924–1925. The filter beds at Madras continue to operate with erratic efficiency. Two batteries of seven filters each with three new ones are unable to turn out the whole quantity of filtered water necessary for the city's consumption, especially during the hot weather. The history of filter beds at Kilpauk is very much the same. A white growth in long trailing filaments is formed in the underdrains, filter chambers and on weirs and with it an odor of sulphuretted hydrogen. A careful study of this growth and of the flora and fauna of the Red Hills Lake formed part of the research work of the laboratory. Experiments on artificial filming of slow-sand filters, chlorination and routine analysis of water were carried on.—*A. W. Blohm.*

Side-Suction Centrifugal Pumps More Efficient for Small Capacity. R. K. ANNIS. Power, 62: 12, 451, September 22, 1925. For small capacities, efficiency of side-suction pump exceeds that of double-suction pump of similar design.—*A. G. Nolte.*

Practical Pointers in the Art of Softening Boiler-Feed Water. L. L. BAKER. Power, 62: 13, 479, September 29, 1925. In an elementary way, author discusses the tests used to control softening, the meaning of various terms and methods of making various tests.—*A. G. Nolte.*

Direct-Current Motors Fail to Start—Testing for the Trouble. B. A. BRIGGS. Power, 62: 13, 485, September 29, 1925. Testing for open-circuits in the field and armature circuits; for fault in the motor; open-circuit in armature and testing series and shunt coils.—*A. G. Nolte.*

Electric Level and Pressure Gage. Power, 62: 13, 504, September 29, 1925. A new electrical level and pressure gage developed by the Republic Flow Meter Company of Chicago is illustrated and described. It may be used to give the head- and tail-water levels in reservoirs, levels in water and oil supply tanks of all kinds, soap vats, etc.—*A. G. Nolte.*

Surface-Condenser Operation. P. H. JEYNES. Power, 62: 14, 514, October 6, 1925. Three factors in surface-condenser performance that present opportunities for effecting economies are: (1) amount of circulating water; (2) period between cleanings; (3) refrigeration or cooling of condensate. Each of these factors is discussed.—*A. G. Nolte.*

Equipment for Crushing Coal. W. W. Sayers. Power, 64: 8, 284, August 24, 1926. Various types of coal crushers are illustrated and described.—*A. G. Nolte.*

The World's Largest Diesel. Power, 64: 8, 287, August 24, 1926. Brief description of the 15,000-hp Diesel purchased by the City of Hamburg, Germany.—*A. G. Nolte.*

Boiler Feed-Water Purification.—9. Priming and Foaming. S. T. Powell. Power, 64: 9, 330, August 31, 1926. Priming is the discharge of water from a boiler with the steam, by the bursting of steam bubbles. Foaming is the production of froth on the surface of the water. This condition is less violent than priming. Priming and foaming may occur at the same time. Construction of boiler has marked effect on priming and foaming tendencies of boiler water. Recently, experience and special studies have confirmed the theory that priming and foaming are due, not only to the concentration of sodium, or other, soluble compounds, but to the presence of these substances in relatively high concentrations in addition to suspended matter. It appears that the basic principle of foam formation is related closely to the surface tension of the liquid. Where foaming is experienced treatment of the water should receive careful consideration. Most efficient means of preventing foaming is to reduce suspended solids to lowest economical point by external treatment. Same applies to soluble solids which may be precipitated within the boiler and controlled by blowing down. Much can be done to prevent foaming and especially priming of a boiler by the way in which it is operated. A number of appliances for the removal of moisture from the steam as it passes from the steam drum have been placed on the market. The author describes and illustrates a number of them. The detrimental effects that result from the use of wet steam are great. All water that leaves the boiler through the steam line carries with it solids, either in suspension or solution. Solids entering steam lines, turbines, engines, etc., create a potentially troublesome and dangerous situation. Wet steam, whether caused by priming or foaming action or merely the result of the mechanical removal of the boiler water due to high velocity of steam travel, is a phase of boiler-water control that deserves most careful consideration.—*A. G. Nolte.*

Boiler Feed-Water Purification.—10. Embrittlement, What Causes It? S. T. Powell. Power, 64: 10, 371, September 7, 1926. Inter-crystalline cracking of boiler steel occurring while boilers are in service is termed embrittlement or "caustic embrittlement." It is distinguished thusly from corrosion cracking or cracks due to stresses. Embrittlement failures are indicated by occurrence of fine cracks in the metal below water line. Two theories have been advanced in order to explain the causes of the trouble. Some investigators claim that primary cause of embrittlement is improper processing of the metal and that the concentration of caustic soda in boiler feed-water is not responsible. Opposed to this view is the theory of caustic embrittlement, advocates of which contend that embrittlement is result of absorption of hydrogen released by decomposition of caustic soda which may take place at high temperatures and pressures and in the absence of other salts (principally sulphates), or at least when these salts are present only in small amounts. Author summarizes the results of extensive experiments by various scientists on embrittlement of boiler metal and sums up the arguments on both sides.—*A. G. Nolte.*

Boiler Feed-Water Purification.—11. Evaporators, Their Design and Operation. S. T. Powell. Power, 64: 11, 406, September 14, 1926. The recent tendency toward high boiler ratings and large-sized boilers and the definite trend in favor of higher steam temperatures and pressures have required much greater purity of feed-water than was formerly deemed necessary. Principle of operation of all evaporators is the same. Evaporators are designated in a number of ways, depending upon certain features of their design or the principle upon which they function. Classified as (1) Submerged Tube Type; (2) Film Type; (3) Flash Type. Classified further according to number of effects as—single effect, double effect, triple effect, etc., classification also made as high-pressure or low-pressure evaporators, also as high-heat-level or low-heat-level evaporators. Author illustrates and describes a number of types of evaporators. Cost of operation of evaporators depends primarily upon source of heat utilized. Choice as to type should be dictated by existing conditions with reference to the particular heat balance of the steam station. Priming and foaming may occur in evaporators. At some stations water is filtered before passing to evaporator.—*A. G. Nolte.*

Boiler Feed-Water Purification.—12. Getting Rid of Dissolved Gases by De-aëration. S. T. Powell. Power, 64: 12, 441, September 21, 1926. Certain gases dissolved in water accelerate its corrosive action. Open feed-water heaters partly remove them, but practically complete removal of dissolved gases is essential in order to stop corrosion. A number of appliances for degasification now in practical operation eliminate practically all dissolved gases. Two most important gases which accelerate corrosion are oxygen and carbon dioxide. There are two general types of degasification apparatus, designated as, (A) Mechanical or Physical and (B) Chemical. Chemical deoxygenators operate by removal of the oxygen from the water by oxidizing iron or steel or other substances. In one type of mechanical deaërator the gases are removed by explosive boiling of the water as it flows through the apparatus. Another type is based upon the principle of reboiling or scrubbing the feed-water by means of live steam; the gases in the water are removed by being forced upward with the rising bubbles of steam. The author discusses the efficiency of deaërators and describes the operation of several types.—*A. G. Nolte.*

Boiler Feed-Water Purification.—13. Corrosion, Its Cause and Cure. S. T. Powell. Power, 64: 13, 471, September 28, 1926. During last century many theories have been proposed to account for failures due to corrosion, namely, the acid theory, the biological, the film, the peroxide, the direct oxidation, and the electro-chemical theories. The latter has been confirmed by a number of investigators. Author briefly explains this theory and further discusses corrosion due to dissolved oxygen, mineral acid, alkalinity of water, carbonic acid, and acid produced from salts in feed-water. Summarized briefly, the principal factors influencing steam-boiler corrosion are as follows: (1) The presence of gases in the feed-water particularly dissolved oxygen; (2) The hydrogen-ion concentration (acidity or alkalinity) of the feed-water; (3) The velocity of the water passing over the metal; (4) The temperature and pressure maintained in the boiler. Author concludes with brief discussion of prevention of corrosion in steam boilers.—*A. G. Nolte.*

Storing Bituminous Coal. W. T. Conlon. Power, 64: 10, 354, September 7, 1926. Loss in heat value from bituminous coal in storage may, in general, be considered as negligible, as it seldom exceeds one per cent of total heat content. There are exceptions, however, and as a rule it is a difficult matter to determine from laboratory analysis. There is at times, a change in steaming qualities of coal due to weathering. The greatest storage loss occurs from spontaneous combustion which is caused by an exothermic absorption of oxygen. In a coal pile with many voids, the oxygen absorbed is automatically replaced, due to air circulation. Filling the voids with coal will by cutting down air circulation and oxygen absorption reduce the likelihood of spontaneous combustion. A suggested method of storing coal is in layers approximating but not exceeding, three feet in depth, by use of drag scrapers or otherwise, keeping in mind that voids should be filled with "fines" and a more or less uniform structure maintained throughout the pile. Rolling and packing give further insurance against fire hazard.—*A. G. Nolte.*

How to Lay Out Power-Plant Piping. S. Crocker. Power, 64: 11, 398, September 14, 1926. The design of pipe hangers and anchors is discussed.—*A. G. Nolte.*

Testing a Surface Condenser in Action. C. E. Colborn. Power, 64: 12, 431, September 21, 1926.—*A. G. Nolte.*

How to Lay Out Power Plant Piping. S. Crocker. Power, 64: 13, 478, September 28, 1926. Heat insulation is considered. The proper thickness and kind of covering for different pipe sizes used under different classes of services is worthy of study. A table of pipe covering standards for various services in the Detroit Edison Company's Plants is given.—*A. G. Nolte.*

Routine Inspection Procedure for Power-Station Equipment. C. R. Reid. Power, 64: 13, 482, September 28, 1926. In large generating stations it is desirable to systematize the work of inspection of the great variety of apparatus. Author gives an excellent résumé of methods of inspection and record keeping in the larger power houses of the Shawinigan Water and Power Company, Shawinigan Falls, Quebec. These methods can be used as a basis for working up a systematized schedule for almost any size or type of plant.—*A. G. Nolte.*

Experimental Studies of Water Purification. (1) Description of Plant. F. J. Moss. Public Health Reports, 41: 40, 2121, October 1, 1926. A brief engineering description is given of experimental water purification plant on grounds of stream pollution investigations laboratory at Cincinnati, Ohio. It is of rapid sand type, similar in its main features to most of the full-scale plants on inland streams in the United States. Some features designed especially for experimental purposes are as follows: provision for delivering to plant river water, domestic sewage, clear dilution water, or a combination of any of these; parallel division of the plant into two independently functioning halves; an unusual flexibility in the arrangement and interconnection of the various units. Plant operated usually during 24 hours each day and six days a week. Routine collection of water samples carried out on an extensive scale. (2) **Preliminary Review of Results of Primary Experiments.** H. W. STREETER. Experiments designed to test the maximum degree of raw water bacterial pollution consistent with production of effluents conforming to given standards of bacterial quality. Experimental plant was arranged so as to permit bacterial content and physical character of raw water to be varied over a wide range. Some of the results of observations indicated: (1) that a consistent relationship exists between the bacterial quality of the raw water and that of the effluents produced from it at successive steps of treatment; (2) that this relationship is a simple power function and can be expressed by a general equation; and (3) that results obtained from the experimental plant may be applied, without substantial modification, to full scale municipal plants of the same type and design and treating raw waters of the same quality.—*A. G. Nolte.*

Bitumen Determinations in Coarse Asphaltic Concretes. A. R. EBBERTS. Eng. News-Rec., 97: 513–4, 1926. Method is described for determining whether bitumen content of asphalt concretes conforms to specifications. By dividing the amount of bitumen specified by the total superficial area of the ideal grading as determined by the specifications, a value termed the bitumen index is obtained. Comparison of bitumen content found on extraction with value obtained by multiplying the superficial area of the aggregate after extraction by the bitumen index, determined as above, shows whether the specimen is of the desired composition. A chart is given for determining the superficial area of the aggregate from the sieve analysis.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Illuminating Gas for Metal Cutting. Eng. News-Rec., 97: 54, July 8, 1926. Illuminating gas has replaced acetylene, hydrogen, and other fuel gases in combination with oxygen metal for cutting at Schenectady plant of General Electric Co., a special torch having been developed for the purpose. Illuminating gas has been found to be cheaper than either hydrogen or acetylene, while cutting speed after starting is approximately equal for all gases. Use of illuminating gas permits use of torch equipped with superheater, thus effecting marked economies in oxygen at cutting jet.—*R. E. Thompson.*

Colorado Springs, Colo. Eng. News-Rec., 97: 17–19, July 1, 1926. The combined hydro-electric and water supply system is described. Supply is derived from southern slope of Pike's Peak. Three of watersheds contain storage reservoirs. Water is delivered from supply lines to 3 distribution reservoirs, from which city is supplied by gravity in two services. Chlorination, by Williams electrolytic method, is employed when necessary. Only 30 per cent of water is metered. Flat rate for 50-foot lot is $15 per year. Meter rate is 15 cents maximum and 8 cents minimum. Maximum consumption is 10 million gallons per day, and per capita consumption 180 gallons per day.—*R. E. Thompson.*

Setting Time of Cement Indicated by a Machine Operation. A. A. Jakkula. Eng. News-Rec., 97: 66, 1926. An apparatus is described and illustrated which automatically indicates the time of set of cement.—*R. E. Thompson (Courtesy Chem. Abst.).*

Flood Protection for Dallas, Tex. Eng. News-Rec., 97: 58, July 8, 1926. Brief data given on revised project for flood protection and land reclamation along Trinity River at Dallas, Tex.—*R. E. Thompson.*

Snow Surveys and Stream Runoff in the Sierra Nevada. Eng. News-Rec., 97: 7, July 1, 1926. Tabulation is given of comparison of actual runoff of 7 basins in Sierra range with runoff predicted by surveys conducted by the Nevada Co-operative Snow Survey. In report on 16 years' snow surveying, J. E. Church, Jr., states that of 54 forecasts made, 29 were within 10 per cent of actual runoff, 14 within 20 per cent, and in remaining 11 maximum divergence was 30.4 per cent.—*R. E. Thompson.*

Well Sinking and Tests for the City of Los Angeles. Geo. R. Shuey. Eng. News-Rec., 97: 8–9, July 1, 1926. Illustrated desciption of methods employed in sinking and testing wells in Owens Valley which are used in times of drought to supplement gravity supply of Los Angeles.—*R. E. Thompson.*

Large Ditch-Lining Job Done at Low Cost and High Speed. Eng. News-Rec., 97: 52–3, July 8, 1926. Description of 1–1½-inch gunite lining placed in east side main canal on Salt River irrigation project in Arizona. The section completed is 16 miles in length and required 4,500,000 square feet of lining. The remaining 16 miles, requiring 3,500,000 square feet of lining, will be completed at close of present irrigation season. Average of 4700 square feet per gun per 9-hour shift was maintained throughout work. Labor cost averaged 1.15 cents per square foot and total cost, including plant, 9½ cents per square foot.—*R. E. Thompson.*

Cylinders for Concrete Samples Made Up on Job. Eng. News-Rec., 96: 1032–3, June 24, 1926. Brief illustrated description of cylinders used on Balch project of San Joaquin Light and Power Corporation which were made at cost of $4 each. Factory-made cylinders for this purpose cost $20 each.—*R. E. Thompson.*

Advantages Shown for Wire-Willow Mattress Over Basket-Weave Type. F. Y. Parker. Eng. News-Rec., 96: 1033, June 24, 1926. Brief illustrated description of type of mattress woven on No. 9 galvanized wire mesh which requires less ballast and $\frac{1}{3}$ less willows, than standard basket-weave type. Bar-growth willows one season old can be effectively used, and cost is about $2 less per 100 square feet.—*R. E. Thompson.*

Effect of Sulfur on Rivet Steel—Summary of Findings. Eng. News-Rec., **97**: 26, July 1, 1926. The Joint Committee on Investigation of the Effect of Phosphorus and Sulfur in Steel of the American Society for Testing Materials report that sulfur up to at least 0.06 per cent is not detrimental. Above this amount many of the strength properties are unaffected, but ductility, impact resistance and shearing strength of riveted joints are decreased. Data obtained presented graphically.—*R. E. Thompson.*

Pipe Line Construction for Athens, Greece. J. P. HANLEY. Eng. News-Rec., **97**: 28, July 1, 1926. Brief outline of construction of pipe line feeding Aciean and Neurvia reservoirs, Athens.—*R. E. Thompson.*

Tests on Growing Vegetation on Gravel Dams. C. H. EIFFERT. Eng. News-Rec., **97**: 55–58, July 8, 1926. Details given of results of experimental plantings on hydraulic fill dams and levees of Miami Conservancy District in Ohio to determine most suitable grasses for providing protective covering for parts of slopes not protected by riprap or revetment.—*R. E. Thompson.*

Tests Show how Calcium Chloride Affects Concrete. A. S. LEVENS. Eng. News-Rec., **97**: 214–5, 1926. The effect of 2, 3, 4, and 5 per cent of $CaCl_2$ as an integral part of mix on the tensile strength of concrete was determined. The strongest concrete was that which contained 2 per cent $CaCl_2$, higher percentages tending to weaken. During the earlier periods (3–7 days) strength of concrete containing 2 per cent $CaCl_2$ was 40 per cent greater than that of plain concrete. Similarly, strength under compression showed an increase of 106 per cent. Shrinkage was 100 per cent greater than in plain concrete at 3 days, 50 per cent at 7 days, and 85 per cent at 14 days and thereafter.—*R. E. Thompson* (*Courtesy Chem. Absts.*).

Rust-Preventive Paints from an Electrolytic Standpoint. E. LIEBREICH. Farbe und Lack, 1925, 602. From Chem. Abst., 20: 995, March 20, 1926. Use of an alkaline salt in priming coat of paint on metal, followed by two coats of durable paint, gives better protection against rust than if alkaline salt is not present to inhibit electrolytic corrosion. Finishing coats prevent water-soluble alkaline salt from being washed out. If ordinary paints were impermeable to water they would effectually prevent rusting. Manner in which moisture penetrates paint films by imbibition is discussed.—*R. E. Thompson.*

Rust-Preventive Materials. JULIUS SWOBODA. Chem.-Ztg., **49**: 977–9, 994–7, 1925. From Chem. Abst., **20**: 995, March 20, 1926. Review of theories of corrosion of iron, of metallic coatings, lacquer, asphaltic preparations, portland cement, heavy mineral oils and greases, metallic soaps, paints, etc., used as rust preventives.—*R. E. Thompson.*

Fighting Rust with Sublimed Blue Lead. The Eagle-Picher Lead Co. Chicago. 82 pp. From Chem. Abst., 20: 964, March 20, 1926. Assemblage of facts concerning properties and uses of sublimed blue lead.—*R. E. Thompson.*

Sectional Concrete Roadway Valve Boxes for Baltimore Water Works. V. Bernard Siems. Eng. News-Rec., 97: 374, September 2, 1926. When concrete vaults were first adopted in Baltimore instead of cast-iron roadway boxes, they were purchased at $2.75 each. Considerable saving has been effected by manufacturing pre-cast sectional vaults at the City yards, 1275 having been made during 1925 at average cost of $1.52 each.—*R. E. Thompson.*

Laying Water Main in Swift Current. Thos. Tremblay. Cont. Rec., 40: 207, March 3, 1926. Brief illustrated description of laying of 16-inch main across St. François River at Sherbrooke, Que. River is 350 feet wide, about 8 feet deep, and has a very swift current. Pipe was installed when river was covered with ice, being lowered into position from wooden trestles erected prior to freezing of river. Work was completed in 7 days by 14 men.—*R. E. Thompson.*

Silicate Protective Coatings for Artificial Stone. F. Huth. Farbe und Lack, 1925, 606. From Chem. Abst., 20: 977, March 20, 1926. Review of use of sodium silicate for hardening concrete floors, artificial building stone, etc.—*R. E. Thompson.*

Concrete Strength Made Uniform by Careful Proportioning. Zara Witkin. Eng. News-Rec., 97: 258–9, 1926. Data given on quality of concrete produced during construction of a building on which 3 field methods were employed, (1) volumetric measurement of aggregates, (2) weight measurement of fine aggregate, and (3) inundation of fine aggregate. Following conclusions are drawn from observations made: (1) Accurate control of water content of aggregates, using same theoretical mix, effected reduction of 6–7 per cent in amount of cement required. (2) With accurate water content control and constant mix, strength is an inverse function of slump. (3) With accurate water content control, strength with same theoretical mix is slightly higher and considerably more uniform.—*R. E. Thompson (Courtesy Chem. Abst.).*

Experiments on Accelerated Testing of Rust-Preventive Paints. Hans Wolff. Korrosion und Metallschutz, 1925, 85: 130; Farben-Ztg., 31: 706; cf. C. A., 19: 2418. From Chem. Abst., 20: 995, March 20, 1926. For accelerated testing, painted panels are placed in glass cylinder through which air of various relative humidities and temperatures, or containing various amounts of corrosive gases, is circulated. Results are compared with those obtained on outside exposure. Exposure of film shortly after drying to strong sunlight is conducive to cracking. High humidity has less effect on drying of white lead paint than on that of zinc oxide paint.—*R. E. Thompson.*

Influence of Sugar on the Properties of Cement. Sucr. belge, 44: 612, 1925. From Chem. Abst., 20: 976, March 20, 1926. Resistance to compression of cement blocks that were made with water containing 0.1 per cent sugar is superior to that of blocks made from cement mixed with pure water. It was also found that wet concrete coming in contact with sugar is stronger than concrete that is merely wet with water.—*R. E. Thompson.*

Procedure for Analysis of Mortars. JAMES L. HEITZMAN. Eng. News-Rec., 97: 271, 1926. Method is described for determining approximate composition of mortars. Weigh out 1 g. of crushed and dried sample, add 50 cc. dilute HCl (1:9) and boil until all soluble material is in solution. Filter, ignite, and weigh. This weight $\times \frac{100}{95}$ = sand content. Evaporate filtrate to dryness cool, add 20 cc. dilute HCl (1:1), warm until Fe salts are in solution and then add 50 cc. distilled water. After boiling, filter, ignite and weigh. This weight × 500 = approximate percentage of portland cement. Dirty sand would introduce an error in this calculation. Determine CaO and MgO in filtrate in usual manner. Calculate the CaO and MgO in the cement by multiplying latter by 0.625 and 0.032 respectively, and subtract these amounts from the total CaO and MgO found. The combined remaining CaO and MgO $\times \frac{100}{95}$ = approximate percentage of lime.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

An Exposure Test of Water-Line Paints. E. F. FIGG. J. Oil Colour Chemists' Assoc., 8: 314–34, 1925. From Chem. Absts., 20: 994, March 20, 1926. Priming coat of red lead in raw linseed oil with finishing coat of white lead in linseed oil tinted with lampblack and two coats of zinc oxide and zinc dust in raw linseed oil gave good protection. Rust inhibition expected from basic lead chromate in raw linseed oil was not confirmed; better protection was obtained with iron oxide-raw oil paints. Use of varnish, in general, decreased durability. Bituminous paints did not show up well. Only one of six commercial paints specially intended for water-line protection gave satisfactory results; this consisted of zinc oxide in slightly thickened linseed oil.—*R. E. Thompson.*

Preparation of Metal Surfaces for Painting and Lacquering. W. J. MISKELLA. Paint, Oil and Chem. Rev., 80: 27, 10–11, 1925. From Chem. Abst., 20: 995, March 20, 1926. Importance of thorough cleaning of surfaces to be painted especially of those to be lacquered is emphasized. Removal of slushing compounds and general cleaning of sheet metal discussed.—*R. E. Thompson.*

Partial Evaporation of Trade Waste Eliminates Taste in Water. R. L. MCNAMEE. Eng. News-Rec., 96: 95–6, 1926. Creosote taste in water supply of Escanaba, Mich., drawn from Little Bay de Noc, was traced, by sampling through the ice, to chemical works discharging considerable volume of wood distillation waste. An arbitrary measure of intensity of taste-producing constituents, termed the taste-index, was employed, being the number of thousand parts of water to which 1 part of sample will impart perceptible taste. Waste from a Myers still, which had a taste index of 300, was found to be responsible for 96 per cent of the taste although its volume was only 1 per cent of total waste of plant. Evaporation of 10 per cent of this waste eliminated 96 per cent of the taste-producing substances. Thus by evaporating 0.1 per cent of total waste of plant, 92 per cent of taste-producing constituents were removed.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

The Softening of Boiler Waters. P. Wiegleb. Chem.-Ztg., **49**: 835, 856–7, 1925. From Chem. Abst., **20**: 957, March 20, 1926. Two methods of water softening are described: (1) treatment with lime and soda, or by permutit system, and (2) mechanical method consisting of preliminary removal of suspended matter followed by evaporation and condensation of boiler water by means of series of evaporators, heat exchangers, and condensers.—*R. E. Thompson.*

Micro-Determination of the Oxygen Content of Water. C. Risch. Biochem. Z., **161**: 465–7, 1925. From Chem. Abst., **20**: 957, March 20, 1926. Sample of water in collector of known volume is treated without exposure to air, with potassium iodide, sodium hydroxide and manganous chloride. Container is closed and shaken for 1 hour in dark and iodine formed titrated with sodium thiosulfate.—*R. E. Thompson.*

Purification of Dairy Wastes. F. Dienert. Lait, **5**: 873–81, 1925. From Chem. Abst., **20**: 959. March 20, 1926. Chemical purification, spreading on soil, bacteriological decomposition, and activated sludge process discussed.—*R. E. Thompson.*

Salt Content of Colorado River Increased in 25 Years. Carl S. Scofield. Eng. News-Rec., **96**: 131–2, 1926. Results of analyses of Colorado River water for 3 yearly periods from October 1, 1922, to September 30, 1925, are given, together with results of similar studies carried out in 1900 and 1905. Salt content ranged from 210 to 1250 p.p.m., means for the 3 years being 896, 839, and 997 respectively, compared with 713 and 723 in 1900 and 1905 respectively. The constituents, expressed as reacting values, during the last year reported were Ca 5.82, Mg. 2.56, HCO_3 3.64, Cl 3.62, SO_4 7.82. The average hardness for the 3-year period was 260 p.p.m. as $CaCO_3$, the percentage hardness, i.e., the proportion of alk.-earth bases to the total reaction units, being 56, 53 and 55 per cent for the 3 years respectively.—*R. E. Thompson* (*Courtesy Chem. Absts.*).

Gravel Wall Well at Leamington, Ont. Contract Rec., **40**: 200–1, March 3, 1926. Principle of gravel wall well is discussed and installation in Leamington, Ont., described briefly. The 3 existing 10-inch wells, 50 feet deep, became inadequate and an 18-inch gravel wall well was installed by Layne & Bowler Company, under contract to supply 400 Imperial gallons per minute. Production of completed well was 438 gallons per minute, compared with combined production of 539 by existing wells, and was only 3 gallons less 1 year later. Power consumption by the direct driven vertical centrifugal pumps is 0.3 kw. hours per 1000 gallons, and cost of delivery of water into reservoir is 0.9 cents.—*R. E. Thompson.*

Methods of Testing the Thickness of Zinc Coatings. HEINZ BABLIK. Metal Ind. (London), 28: 33–5, 1926; cf. C. A., 19: 2629. From Chem. Abst., 20: 896, March 20, 1926. Experimental results show that increase in weight after zinc-coating is no measure of amount of coating. Author believes reagents proposed by Bauer (concentrated sulfuric acid 20 grams, water 500 cc., and arsenious oxide 2 grams) and by Aupperle (concentrated hydrochloric acid 100 cc. and 5 cc. of solution prepared by dissolving 20 grams of antimony oxide in 1000 cc. concentrated hydrochloric acid) are best. Defects in gas-evolution and temperature-increase methods are pointed out.—*R. E. Thompson.*

ABSTRACTS, SUBCOMMITTEE NO. 9

JOINT RESEARCH COMMITTEE ON BOILER FEEDWATER STUDIES

Utilization of Condensing Water for Boiler-Feed Purposes (Die Frage der Kondenswasserverwertung für Kesselspeisezwecke). A. STERN. Wärme, 49: 50, December 10, 1926, pp. 868–870, 1 fig. Advantages and disadvantages of lime in feedwater; boiler corrosion due to air in feedwater; enrichment of air in feedwater by use of feed pumps; automatic boiler-feed plants which prevent absorption of air; how high-pressure boilers should be fed.

Boiler Disencrustants. A. SETON. Eng. & Boiler House Rev., 40: 7, January 1927, pp. 364–365. Deals with softening of water in boiler whereby formation of scale is prevented to some extent, and discusses disencrustants of different makes.

Complete Removal of Oil from Feedwater (Hot volkomen olie-vrij maken van het voedingwater). J. C. DIJXHOORN. Het Schip, 8: 23, November 12, 1926, pp. 332–333, 1 fig. Application of Dijxhoorn system of oil separators; as example 1 kg. sodium salt and 3 kg. alum are used to treat 24 tons feedwater.

Feed Water Preparation. Power Plant Eng., 31: 2, January 15, 1927, pp. 119–129, 14 figs. Feedwater heater; water and steam purification; present status of economizer practice.

Principles of Modern Specifications for Boiler Feed-Water (Neuzeitliche Beurteilungsgrundsätze für Kesselspeisewasser). A. SPLITTGERBER. Zeit. für angewandte Chemie, 39: 44, November 4, 1926, pp. 1340–1345. Necessity of careful analytical control of boiler feedwater, before and after softening, for efficient and economical running, is emphasized, and methods of softening are described.

Feed Water Treatment in Power Plants. Power Plant Eng., 31: 1, January 1, 1927, pp. 25–28, 2 figs. Higher steam pressures and demand for higher ratings have made feedwater treatment problem of vital importance.

Railroad Water Treatment. West. Soc. Engrs. Jl., 31: 10, October, 1926, pp. 392–402 and (discussion) 402–407. Contains three papers giving general view of water-treating practice on American railroads, as follows: **History**

and Growth of Water Treatment for Locomotive Boilers, R. E. COUGHLAN; General Aspects of Water Treatment for Railroads, R. C. BARDWELL; Zeolite Method of Water Softening, C. STURDEVANT.

Recent Developments in Feed-Water Treatment. E. H. TENNEY. Power Plant Eng., 31: 1, January 1, 1927, pp. 23–24, 2 figs. Practice in chemical methods of treatment, evaporation deaëration, and stage feedwater heating.

Recent Influences on Boiler Water Treatment. J. D. YODER. Power Eng., 30: 24, December 15, 1926, pp. 1316–1318, 2 figs. Of many recent innovations in power plant design, those closest related to boiler-feedwater treatment have been higher ratings and higher pressures at which it has been found economical to operate boilers; hot-process water softener; use of trisodium phosphate; maintaining proper sulphate-carbonate ratios.

The Scientific Treatment of Boiler Feed Water, Introducing the Colloidal Aspect. W. B. LEWIS and S. G. IRVING. Ceramic Soc.—Trans., 25: 1925–26, pp. 200–205 and (discussion) 205–208. Application of colloidal chemistry to feedwater problems; water-softening plants; oxygen and corrosion.

The Origin and Prevention of Corrosion in Boilers (Die Entstehung und die Verhütung von Korrosionen in Dampfkesseln). P. WIEGLEB. Brennstoff u. Wärmewirtschaft, 8: 22, December 1, 1926, pp. 369–373, 2 figs. Discusses four causes of corrosion by feedwater, namely: gases dissolved in water, insoluble and soluble materials, and volatile acids.

Boiler Protection and Maintenance. Mar. Engr. & Motorship Bldr., 49: 592, December, 1926, pp. 466–467, 1 fig. Particulars of filtrator, a simple device which prevents formation of boiler scale.

Boiler-Scale and Rust Prevention in Hot Water (Die Verhütung von Kesselstein und Rost in heissem Wasser). M. GROECK. Gesundheits-Ingenieur, 49: 48, November 27, 1926, pp. 740–742, 1 fig. Describes Riwog water-transformation process, according to which lime and corrosion problem is solved.

Cleaning Condenser Tubes. Power, 65: 2, January 11, 1927, p. 64. Laboratory experiments by Elliot Co. indicate that proper acid concentration to use in removing condenser-tube scale is 2.5 per cent solution by volume of hydrochloric acid for treatment of one hour's duration.

Scale Prevention on Fire Tube Boilers. Universal Engr., 44: 6, December 1926, pp. 25–26, 1 fig. Survey of heavy scale formation in boilers of Monmouth Memorial Hospital, Long Branch, N. J., resulting in installation in 1923 of De-Concentrator supplied by Hagan Corp.; De-Concentrator has entirely prevented formation of scale, sediment remaining in boiler being soft and readily washed out, and small in amount as compared with former quantity of scale.

Feeding Locomotive Boilers (Ueber die Speisung des Lokomotivkessels). D. R. P. Wagber. Verkehrstechnik, no. 47, November 19, 1926, pp. 801–805, 6 figs. Discusses development of feedwater heaters; flue gas heaters; preheaters; steam jet pumps; exhaust preheaters; quantity of heat consumed and delivered by various types.

Direct Titrometric Methods for Magnesium, Calcium, and Sulphate Ions and Their Application in Water Analysis. E. P. Schoch. Indus. & Eng. Chem., 19: 1, January, 1927, pp. 112–115. Titration of magnesium, calcium, and sulphate; determination of permanent hardness or of sodium carbonates in natural waters; determination of amounts of lime and soda required to soften water.

Water Softening Problems and Their Remedies. F. S. Taylor. Water Works Eng., 79: 24, December 15, 1926, pp. 1579–1580 and 1607–1608, 5 figs. Some troubles experienced in new electric plant; how these were met and overcome and excellent results obtained.

Effect of Hydrogen-Ion Concentration in Revivifying Zeolites. O. R. Sweeney and R. Riley. Indus. & Eng. Chem., 18: 12, December, 1926, pp. 1214–1216, 5 figs. It is shown that pH value of water softened should be important control constant for all waters for use in commercial softeners.

NEW BOOKS

Druckrohrleitungen: Berechnungs- und Konstruktions- Grundlagen der Rohrleitungen fur Wasserkraft- und Wasserversorgungsanlagen. Felix Bundschu and Adolf Ludin. Berlin: Julius Springer. Paper; 6 × 9 inches; pp. 60; illustrated. 6 reichmarks in Germany. Reviewed in Eng. News-Rec., 97: 674, October 21, 1926.—*R. E. Thompson.*

Von der Bewegung des Wassers, und den dabei Auftretenden Kräften: Grundlagen zu einer praktischen Hydrodynamik für Bauingenieure. Alexander Koch and Max Carstanjen. Berlin: Julius Springer. Cloth; 8 × 10 inches; pp. 228; 331 halftones and line cuts; 2 folding plates. 28.5 reichmarks in Germany. Reviewed in Eng. News-Rec., 97: 675, October 21, 1926.—*R. E. Thompson.*

Theory of Water Hammer. Lorenzo Allievi. Translated by Eugene E. Halmos. Printed in Rome, Italy. Paper; 7 × 11 inches; two volumes, 119 pp. of text in one, 44 plates in other. Copies may be had free of charge from either American Society of Civil Engineers or American Society of Mechanical Engineers, 33 W. 39th, St., New York City. Reviewed in Eng. News-Rec., 97: 675, October 21, 1926.—*R. E. Thompson.*

Descriptive Bibliography on Oil and Fluid Flow and Heat Transfer in Pipes. Technical Series Bulletin, Missouri School of Mines, Rolla, Mo. Joe B. Butler. This bulletin of 62 pages lists and describes 370 references to published articles and books. The references are arranged chronologically as to year of publication, are fully cross-referenced, and are indexed as to subject, author, and periodical. A short article on the flow of oil in pipes gives formulas, data and procedure in solving problems.

All articles with data on friction loss and heat transfer in oil flow are included. Of the articles on flow and heat transfer in pipes of water, air, steam, and gases, only those with data pertaining to fluids in general are listed. Articles on critical velocity, viscosity and viscosimetry are included if they have applications to oil or fluid flow in pipes.

In 1914, Stanton and Pannell experimentally established for fluid flow in pipes that the friction factor in the ordinary hydraulic formulas is a function of the ratio of the inside diameter of the pipe times the average velocity of flow times the specific gravity of the fluid divided by the absolute viscosity of the fluid. Curves showing this relation over both the streamline and turbulent régimes of flow are plotted from experimental data on water, air, oil and steam. The author lists 51 references having data or curves applicable to oil over both régimes of flow.

Copies of this bulletin may be obtained by writing to the Librarian of the Missouri School of Mines, or to the author.

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PROTECTING THE WATER SUPPLY SYSTEM IN SUBWAY CONSTRUCTION IN NEW YORK CITY[1]

By Robert Ridgway[2]

A wholesome water supply in abundance and an adequate local transit system are essential to the well-being and healthy growth of a large city. Both are of major importance to the communities they serve. It is not necessary to point out to water works men the importance of a water supply. Without it, the city could not exist. New York is blessed in this respect, thanks to men of vision and ability like those who have just addressed you. But transit is of primary importance, and the task of those responsible for it is a difficult one. If transit does not keep pace with the need for it, the city's growth and development are seriously impaired. I suppose we shall never catch up in this city. Car riders increase in number about as the square of the increase of population, and it is difficult to provide facilities at this rate, especially as each new transit line has a way of costing more than its predecessors. If subways ever catch up with the need for them, we will need a large addition to the water supply to provide for the great increase in population that will follow.

The water supply engineer has one advantage over his brother in the transit field, in that most persons assume that his work is well done, and pay little attention to him unless a main breaks, or a "Committee on Rumors" reports that a mysterious hole has appeared in the impervious bottom of a reservoir. On the other hand, every car rider is interested in transit, because he uses the lines every day and is familiar with their shortcomings and defects. Naturally his criticisms are not always just or constructive.

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[1] Presented before the New York Section meeting, December 29, 1926.

[2] Chief Engineer, Board of Transportation, New York, N. Y.

It is difficult in a large city like this for all interests to unite on a transit plan. When the latter is finally adopted it is the result of the workings of many minds and interests. Just now we are building a new subway system in New York which is to traverse Manhattan and extend into three of the remaining four boroughs of the city, Richmond being the exception. As an example of the cost of subway construction today, it is estimated that the 57 miles of route with its 170 miles of single running track will cost to construct and equip, including engineering, administration and cost of money during construction, about $600,000,000. The main four-track trunk of the system in Manhattan is on the west side, extending from 207th Street and Broadway to Fulton Street, thence under the East River to Brooklyn. In the middle section of the city it is located under Eighth Avenue.

When William Barclay Parsons designed the first subways built in this city a quarter of a century ago, after careful consideration of the whole matter, he decided to build them, wherever the topographical conditions would permit, as close to the street surface as practicable. This was a wise decision for a number of reasons—among others, it reduces the climbing at stations, avoiding the use of escalators and elevators, this making for convenience and economy. This general plan is still believed to be the preferable one, and is being followed today. It has, of course, objections which would not apply to deep tunnel construction. During the construction period it requires the tearing up the streets which interferes with the street traffic, means much readjustment of the subsurface utilities, and introduces hazards of construction to provide for which expensive safeguards are necessary. Perhaps the time is not far away when deep tunnel construction will be used for future subways in Manhattan, because with the many that are now here, it is necessary to go quite deep with the new structures wherever the latter have to pass under existing ones,—in some cases to the third level below the street. The deep tunnel, however, would not be a simple thing to construct. It would be difficult to excavate a cavern in the rock large enough for a four-track station under a city street, and more difficult if the material was saturated sand. Then to handle the rush-hour crowd in stations far below the surface would require the installation and operation at a great expense of large batteries of large elevators.

SUBWAY CONSTRUCTION AND SUBSURFACE UTILITIES

If the building of a subway was merely the digging of a trench, erecting the structure and backfilling and restoring the street surface, the task would be difficult enough, but added to this is the care of the buildings adjacent, a large percentage of which require expensive underpinning, and the maintenance, support, and restoration of the hundreds of miles of subsurface utilities, such as water mains and steam mains, sewers, telephone and electric light cables. The direct and indirect cost to the city for the care of these subsurface utilities, exclusive of the underpinning of the buildings averages probably 15 per cent of the cost of the subway construction. As an example of how these costs run up, the expense of restoring the telephone and Edison cables on the half mile of subway under Eighth Avenue between 111th and 121st streets, exclusive of the cost of laying the ducts, is about $285,000. In this stretch, there are about 20 miles of telephone cables alone to be redrawn.

Before the work is placed under contract, a careful survey is made of the subsurface conditions, as far as it is possible to do so, and the information is plotted on a scale ten feet to the inch, the drawings being furnished to the bidders. Of course, the information cannot be guaranteed, but it is generally correct. Incidentally, the work of preparing the information for the bidders is quite burdensome because of the complicated subsurface conditions.

The New York subways are generally of the two-track or four-track type. Normally all tracks are at the same level, but frequently where economy of construction will result, the structure is double decked. Under Central Park West, for example, the four-track subway now being constructed is of the double-deck type, the upper tracks being for northbound traffic and the lower ones for the southbound traffic. The typical four-track subway railroad which we are building has an overall width of about sixty feet and a height of about seventeen feet. There are many variants from this type determined by local conditions and connections to be made with existing railroads.

In general, subways are located as near to the street surface as is

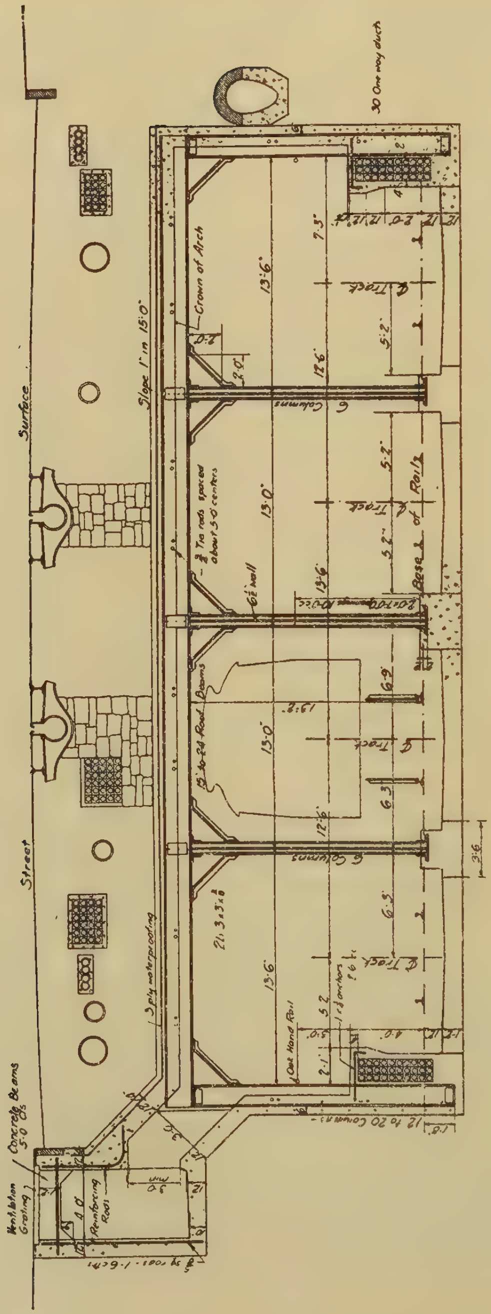

FIG. 1. CROSS SECTION OF THE STANDARD 4 TRACK SUBWAY ON ONE LEVEL WITH THE PROVISIONS FOR VENTILATION AND VARIOUS SUB SURFACE STRUCTURES. SEWER AT EXTREME RIGHT

practicable to reduce the amount of excavation. In this matter, we are governed by the underground structures which are encountered. As a rule we endeavor to have 6 feet of cover over the subway roof and follow generally the grade of the street surface. But on account of the presence of existing subways or important underground structures which have to be crossed or because the grades of the streets are greater than can be used on tracks, or when the subway approaches rivers under which it is to be carried, greater depths of cover are secured which may at times be so deep that tunneling is used. It is evident, therefore, that with the shallow type of subway which we are building, serious interference results with the underground structures, such as gas mains, ducts for lighting and telephone cables, water mains, steam mains, pneumatic tubes and sewers, requiring at times radical rerouting and rearrangement of these structures. Next to ducts with the cables within them and sewers, the greatest difficulty and expense is entailed with water mains. These normally have four feet of cover and most of them vary in size from 12 inches to 48 inches in diameter, and, therefore, with about 6 feet of cover over the subway roof, interference with the larger water mains often results. This is particularly the case at street intersections where the structures on the avenue and on the intersecting streets occupy different levels.

CARE OF WATER MAINS IN SUBWAY CONSTRUCTION

Every engineer and contractor engaged in subway construction has a wholesome respect for the water main and realizes that a break, especially in one of large calibre, means trouble and damage; therefore, every precaution is taken to support them properly and they are carefully watched, a caulker being on hand to correct any small leak that may occur. A 48-inch water main is looked upon with the same degree of respect as is a dynamite magazine, and is believed to have about the same potential power for damage if it should "let go." The damage cannot be lightly regarded because breaks have occurred from time to time which have flooded the construction workings and, on several occasions, the operating subways with serious results. If it could be done, subways would be kept away from these large mains, but that is not possible.

The manner of supporting five 48-inch mains on Central Park West which lead from the Catskill Aqueduct shaft in the Park at 106th Street is shown in figure 2. I-beams spanning the pipes

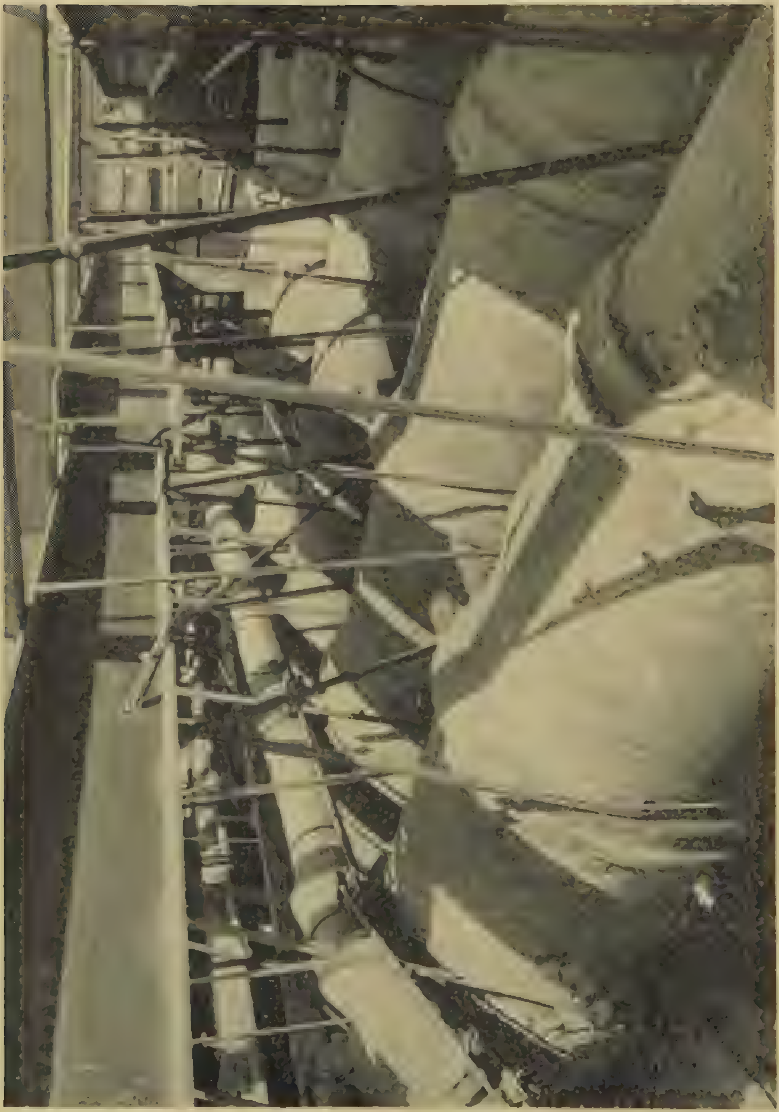

FIG. 2. METHOD OF SUPPORTING FIVE 48 INCH CAST-IRON WATER MAINS ABREAST IN A PORTION OF THE SUBWAY CUT IN CENTRAL PARK WEST

were supported on the street surface, and the pipes were hung from them by means of wire cables guyed in several directions to prevent lateral movements as well as vertical settlement of the pipes while the rock was blasted and removed below them. These supporting beams were an obstruction to the street surface, but it was considered better to endure this inconvenience than to risk supporting the pipes from below as it was feared that the blasting might knock the supports out with disastrous results. We will all be glad when these five pipes are permanently supported on the subway roof. This is but one of many interesting details of water main support which can be seen along the line of the work.

Along the line of the new subway new being built in Manhattan from Fulton Street to Washington Heights, a length of about fifteen miles, there exist about three miles of high pressure water mains and about thirty miles of low pressure mains ranging in size from 6- to 48-inches. The high pressure mains extend only as far north as 34th Street. Not all of these mains are interfered with, but most of them have to be supported, relocated or even replaced in their new positions with new mains. In some instances the water mains have to be rerouted through different streets.

GENERAL CARE OF WATER MAINS

Where new mains have to be laid, they are made to conform to the standards and requirements of the Department of Water Supply. Recently in cooperation with that department we have been using steel pipe more extensively than heretofore for the larger sized main. This has been done to reduce failures in pipes which, it is feared, might occur where mains are laid in disturbed material or fill. Cast-iron pipe, if subject to excessive stress, fails without warning, whereas steel will deform without failure. Cast iron mains fail suddenly and cause a great deal of damage, whereas steel pipe gives warning of deterioration by leaks through cracks or pinholes which have developed, so that it can be repaired before any material damage has resulted. The repairs of cast-iron pipe must be done at once when the failure has occurred, which always prove expensive. Steel pipe can be repaired after the situation has been studied, if the leakage is slight, and the repairs can therefore be made more economically.

The construction contracts make suitable provision for the care of the water mains and other utilities and the requirements concerning them are clearly outlined there and in the drawings. Further provisions are made in the new contracts to avoid failures of water mains where laid in backfill. At such locations the mains, whether of steel or cast-iron, will be supported from either the subway roof or undisturbed material by means of a concrete cradle carried on a reinforced concrete trestle, consisting of a floor with piers about ten feet apart.

Where the cover of the subway is small or the main is large, it is necessary to carry the main through a depressed bay in the subway roof with a vertical reverse curve at each end. If the top of the pipe is less than three feet from the surface the pipe is protected against shocks from roadway loading by means of a reinforced concrete slab above it carried by a pier on each side of the pipe reaching to the subway roof.

WATER SERVICES

Ventilating chambers are provided for the subway at comparatively frequent intervals which lead from the subway roof to the sidewalks or park areas where the openings are covered with gratings. These interfere at times with the various services to buildings. At intervals spaces called "blind bays" are left between the ventilating chambers so that most of the services can be kept outside and independent of the railroad structure. At times this is not possible. In such cases ferrules are provided through the ventilator chambers through which the services are carried. With water services through ventilators, additional precautions are necessary to prevent freezing from exposure to the atmosphere in severely cold weather. After an exhaustive investigation carried on in a cold storage place checked by calculation, a design was developed for protecting exposed water service from freezing. This consists of increasing the water service to a minimum size of two inches carried through a ferrule covered with three layers of one inch hair felt and tar paper, the whole protected with an outside ten-inch steel ferrule. This construction is extended at least two feet into the adjoining ground on each side of the ventilating chamber.

LOCATION OF CENTRAL PARK WEST SUBWAY

Between 59th and 110th Streets the new subway is under Central Park West. In this stretch we have encountered about 30,000 feet of water mains, of which about 8800 feet are 48-inch, 3800 feet are 36-inch, and 4200 feet are 30-inches in diameter; the remaining pipes

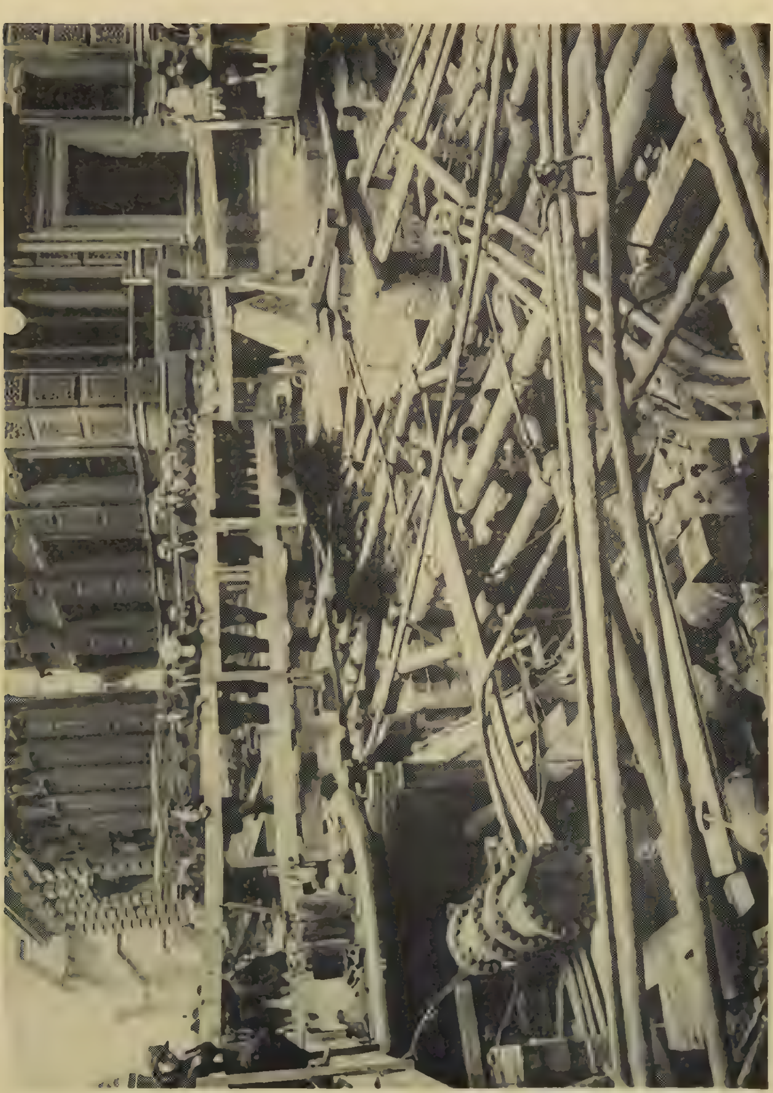

FIG. 3. COMPLICATED SYSTEM OF PIPES BENEATH STREET SURFACE ENCOUNTERED IN SUBWAY EXCAVATION IN WILLIAM STREET AT THE CORNER OF WALL STREET

vary from 12- to 20-inches. The subway structure in this location was designed and located with particular reference to the existing water mains. The subway was made of two levels, each having two tracks to reduce the width of the structure, thus avoiding as far as possible interference with the mains; north of 94th Street the railroad was located on the west side of the Avenue because there are four to five 48-inch mains on the east side between 100th and 106th Streets. South of 92nd Street the subway was located on the east side of the Avenue because then the water mains and underground structures lie mostly on the west side. North of 106th Street the subway was gradually changed from two levels to one level and was continued north of 110th Street in Eighth Avenue rather than turning to the west, because of the existence of six 48-inch water mains in Manhattan Avenue, one block west of Central Park West.

72-INCH CAST IRON PIPES IN CENTRAL PARK WEST

In Central Park West, between 85th and 90th Streets, two abandoned 72-inch cast-iron pipes were uncovered by the subway excavation. These pipes originally led from the gate house at about 92nd Street and Columbus Avenue to the Central Park Reservoir, and gave considerable trouble. They were finally replaced with three 48-inch cast-iron pipes, two in Central Park West and one in 85th Street.

Mr. Edward Wegmann in his "Water Supply of the City of New York," pages 77 and 78, gives the following account of these pipes:

> Change of the aqueduct from 85th to 92nd Street. An act passed by the Legislature in 1865 obliged the Croton Aqueduct Department to remove the masonry conduit from 85th to 92nd Street (where it was considerably above the level of the adjoining lots and interfered with the grading of the streets) and to substitute for the same iron pipes laid below the ground, or a depressed masonry aqueduct. This measure, which had been contemplated for some years, had been steadily opposed by the Croton Water Board which claimed that all damages caused to the lots through which this high part of the aqueduct passed had been paid for when the work was constructed. At that time, however, no person anticipated the wonderful growth of the city. The change, although expensive, was a great improvement. The masonry conduit was torn down, within the limits mentioned above, and replaced by two lines of cast-iron mains, 6 feet in diameter, which were located as shown on Plate 10. The connections of the masonry conduit with the pipes were made by suitable masonry chambers.
>
> The contracts for the materials and work were made in the latter part of 1864, and the work was commenced in 1865. The pipes were furnished by S.

Fulton and Company, of Philadelphia, and R. P. Parrott, of the West Point Foundry. The contract for grading the line and for laying the pipes was awarded to F. L. Brown and John Wetherell, of New York.

The cost of making the change was estimated at $310,000, but exceeded this amount on account of the breaking of some of the pipes when subjected in the summer of 1867 to water pressure for the first time. Out of 480 pipes, eighteen were cracked at the hub and one at the spigot end. The cracks varied in length from 2- to 33½- inches, with the exception of two which were respectively 3 feet, 8¾ inches and 8 feet 9 inches long. They varied in width from a merely perceptible line to ⅛ inch. The cracks occurred invariably for their whole length in or near the center of the bottom of the pipe. The broken mains were repaired by cutting off the hubs and pipes, as far as the cracks extended, replacing them by strong cast-iron sleeves (see figure 16 and plate 10), and, where required, by short lengths of pipe.

Various theories were advanced to account for this failure. The facts in the case were fully discussed by Mr. A. W. Craven, at the time Chief Engineer of the Croton Aqueduct Department, in a paper read before the American Society of Civil Engineers on January 29, 1868. Mr. Craven inclined to the opinion that the failure was due to water-ram caused by shutting the inlet-gate, while the outlet of the pipes was closed. It does not seem, however, that any great water-ram could have occurred. The maximum "head" was only 14.54 feet; the inlet-opening had an area of 2¼ square feet, while the area of the two 6-foot pipes was 56.5 square feet. Great care was taken in filling the mains. In the paper mentioned above Mr. Craven states:

"Whatever be the real cause of this failure, I am convinced that if large pipes must in any case be used, an alteration should be made in their shape. If again obliged to use pipes of this caliber under similar circumstances, I would increase the thickness to 2 inches. This would diminish the chance of injury during the cooling of the metal. I think, also, that in pipes of very large size additional security would be ensured by dispensing with the hub or bell ends, and using sleeves as the means of making the joints."

The 6-foot pipes which were laid at the place in question had a thickness of only 1⅝ inches. The foundations upon which they were placed consisted principally of street embankments into which large stone and earth had been dumped without any special care. Mr. Craven states, however, that no settling of any account had occurred when the failure took place, and that some of the pipes ruptured had been laid on rock. Breaks in the 6-foot mains continued to occur until finally the Department of Public Works replaced these pipes by three lines of 4-foot mains.

WATER MAINS WITHIN THE SUBWAY

Efforts to avoid carrying water mains within the subway railroad have succeeded in all cases, excepting in the old subway under Lafayette Street at the Spring Street and Bleecker Street Stations. This subway was built at these locations with very little cover over the subway and little clearance on the sides of the stations to the building lines so that the 36-inch water main in this street was located under the east platforms of both the Spring and Bleecker Street Stations. Diverting the main through another street was considered too expensive. Breaks have occurred in this 36-inch main at various points at the normal depth with about 4 feet of cover over it. No breaks have ever occurred in the portions under the platforms. In about 1910 the water mains under the platforms were strengthened by surrounding them with concrete to reduce the danger of a break and consequent subway flooding which would be most serious. In the early part of 1921 an additional gate was installed on this main at Broome Street, making it possible to shut down the main under the stations by closing eight valves whereas previously at least fifteen valves had to be operated. In connection with the break of the main on this line on April 23, 1921, it was necessary to close seventeen valves which took eighty minutes. Additional valves must be closed to relieve pressure on the main gates. The main under the platform has a solid bearing and no concern is felt by the Department of Water Supply for its safety.

In Greenwich Street, between Liberty and Dey Streets, a 20-inch pipe pressure water main was located close to the building line on account of the lack of cover over the subway structure. This pipe was strengthened by surrounding it with reinforced concrete to minimize danger of breaks and thus safeguarding the buildings and their foundations.

CROTON AQUEDUCT

The old Croton Aqueduct has been encountered on the new subway at two points—at St. Nicholas Avenue, 153rd to 154th Streets, and at Central Park West at 92nd Street. The old aqueduct was built of brick and rubble masonry, horse-shoe in sections, 8 feet 5½ inches high by 7 feet 5¼ inches wide. This is being replaced at the points of interference across the subway roof by 96-inch steel pipe, ⅜ inches thick, lined with 4 inches of cement mortar and enveloped with about 8 inches of concrete. The grade of the subway was kept down to permit this construction over it. The new masonry section connecting the steel pipe with the old undisturbed aqueduct will be of reinforced concrete of the same interior dimensions as the old aqueduct. About 360 feet of new aqueduct are required, of which about 100 feet are steel pipe as described. The *new* Croton Aqueduct in Amsterdam Avenue at 162nd Street and St. Nicholas Avenue is a circular masonry lined pressure tunnel 12.25 feet in diameter and has a depth of cover over it of about 140 feet. The new St. Nicholas Avenue subway now under construction crosses over it without interference, the depth of the subgrade being somewhat less than 50 feet.

CATSKILL AQUEDUCT IN MANHATTAN

The depth of the Catskill Aqueduct is so great that the subway workings do not approach it, but do approach several of the shafts. At such points the subway was located so as not to interfere with them. The drains from these shafts which discharge into the nearby sewers have had to be relocated on account of subway interference.

In Brooklyn and Queens, considerable study has been given in fixing the relative locations of the Catskill steel conduits and the subway structures. The steel conduits vary in size from 48- to 72-inches in diameter.

In Queens along East Avenue a 72-inch steel conduit was located under the sidewalk of East Avenue and Jackson Avenue to allow room for a future subway. In Ely Avenue the conduit was terminated near Nott Avenue on account of a proposed subway in this Avenue. The conduit in East Avenue was built as an inverted siphon under the existing I. R. T. subway in 4th street.

PRECAUTIONS WITH GAS MAINS IN SUBWAY CONSTRUCTION

The contracts for subway construction require that the streets be decked so that the usual traffic can be carried on over the excavation. After the pavement is taken up, and the first shallow cut made, the decking is placed, the remainder of the work being carried on under this deck. Before the decking is placed, however, a temporary by-pass gas system is installed, the service mains being laid in the gutters and the house connections carried to them. The larger mains are carried on trestles over the sidewalk or in special locations on the sidewalk. It is the inflexible rule to have no live gas mains under the street decking. This by-passing system is a considerable item of expense, but it is justified on the ground of public safety.

SUPPORTING SUBSURFACE UTILITIES

As the excavation is made it is necessary, of course, to support the subsurface utilities encountered and the timbering of the trench is designed with this in view. Usually the sewers are broken out and spiral riveted pipe substituted for them. The water, gas, and steam mains are supported on the temporary timbers or steel supports. The telephone and electric light ducts are broken away, and the cables are either boxed or carried in some other way that will preserve them from injury so far as practicable. The contracts require that all of these utilities be maintained in a condition to furnish their usual service, and to the credit of the contractors it should be said that there has been little cause for complaint in this respect. It is very unusual for any service to be out of commission. The contractors have developed many interesting and efficient methods of support.

In the course of subway construction during the past twenty-five years, hundreds of miles of water mains have been exposed. When the work was begun in 1900, it was the idea of others besides myself that we would discover wholesale leaks in these mains, and that seemed to be the general impression at the time. These wholesale leaks were not found and based on an experience covering over a quarter of a century, I have a great respect for the engineers past and present who installed the water mains underlying the streets of New York. The leaks disclosed in our excavations have been remarkably small in number and amount. I think this is an excellent showing, considering the fact that the mains were laid by many men at many times, covering a period of sixty years or more. The standards of the department must have been good standards to achieve such results.

I wish to acknowledge my indebtedness to S. D. Bleich, Assistant Division Engineer of the Board of Transportation, for his assistance in getting the facts for this talk. Mr. Bleich acts as Designing Engineer in charge of the studies for rearrangement of the sewers, water mains, and other subsurface utilities with which the subway construction interferes. He has a high standing with us as an expert in such matters.

DISCUSSION

Wm. W. Brush:[3] Mr. Ridgway was first a water supply engineer then became a subway engineer. He is, as we all know, a very competent engineer in both fields and very sympathetic to the water

[3] Chief Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

supply problems in his present field of subway engineering. He has gone to great length to devise methods of supporting the water mains during construction, and after the subway is constructed to prevent those mains from settling and breaking.

The supports shown indicate that an effort is being made to make the span between points of rigid and sufficient support a safe span for the water main. There certainly does not seem to be a sound reason for putting a water main in the ground, later disturbing the foundation under that water main, and then backfilling with material that you know beforehand will settle and trust that your large factor of safety in a water main will be sufficient to meet the stress that will come from settlement. Under the present construction of subways, these mains are supported rigidly and adequately as they pass over or along the subway route and then in intermediate disturbed ground are safely carried to the original earth that has not been in any way disturbed. That plan will make for safer construction, will undoubtedly reduce very substantially the breaks, and represents an advance in the art of supporting the water mains after the subway is constructed.

Mr. Ridgway showed the method of protecting services against freezing. Those of you who have the problem of protecting service pipes will obtain very interesting and helpful data if you should ask Mr. Ridgway to furnish you with the information that was obtained and recorded as a result of the extensive tests that were made and experiments carried on by the Board of Transportation or its predecessor under Mr. Ridgway's direction. I think those are the most helpful tests that we have in the water works field for protecting service pipes from freezing.

The subway contractors may have unbounded respect for the water mains, but they blow them out every once in a while, not intentionally, but you cannot control the men who are trying to get the rock out quickly and economically. We depend upon the subway force to see that the water mains are safeguarded and that the valves are not operated. We have only a general inspection by our force. The construction engineer on the subway is primarily interested in getting the subway built, and I think he is conscientious in his attempts to see that the water mains are protected; but it is very difficult when you are working underground to see that somebody connected with the contractors does not operate a gate when he is supposed to leave the gate alone, or that he does not blow out a water main when he is supposed to see that the water main is adequately protected from the rock that may be dislodged by a charge.

Building subways is a big job. We cannot expect the rock to be taken out piecemeal by channelling, wedging, or barring because that represents a big cost to the city of New York. It is better to lose a water main once in a while than it is to subject the city to the very large cost that would result from attempting to carry on the work without blasting in the vicinity of water mains.

Alexander Potter:[4] I should like to ask Mr. Brush a question. In pictures shown on the screen a veritable net-work was indicated of pipes and water mains, probably laid at different times. Has there been any effort made to remove a number of those pipes and replace them by larger mains so as to occupy less area of the street?

Wm. W. Brush:[3] There has not been a very extensive effort made to do so. As a rule we only have one service main in the street, unless it is a case of where a 12-inch or larger main was laid to replace a small main that had failed to be sufficient to meet the needs of that particular area, and where the old main was left in and to be removed when the street is repaved. We do try, with the help of the transportation engineers, to simplify our water supply system when subways are built; and when the mains are relaid, they are relaid in the manner that will reduce to a minimum the number of mains in the street, but usually where there are two or more mains in a street each main has a specific use which would not be served if we took out the two, three or four, as the case may be, and substituted one or more larger mains.

In New York, our plan is to have every trunk main in the city one that can be taken out of service in case of need and left out of service for a period of several days or weeks without any serious impairment as to pressure or fire protection. We have a very serious problem that might develop due to our depending upon the integrity of the Catskill tunnel within the city limits for the greater part of the supply to all of the boroughs. The Board of Water Supply has been working on that problem to furnish a second tunnel so that we will have a substitute and in part an addition to our carrying capacity that will take care of present needs and some of the prospective future needs.

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[4] Consulting Engineer, New York, N. Y.

ROBERT RIDGWAY:[2] As far as the subway construction is concerned there has been very little trouble with unnecessary duplication of water mains. There is a duplication of gas mains due to the fact that in the past there were half a dozen more or less companies. They are consolidated now under the Consolidated Gas Company. Years ago when the subway trenches were open the suggestion was made that one large main be substituted for several smaller ones. At that time the gas company was opposed to it. Now they are taking the initiative in the matter and I think there is a fair chance of substituting one large gas main on Eighth Avenue for the half a dozen more or less smaller ones that are there today. When one considers that there must be brought into agreement the officers and bondholders of the Consolidated Gas Co. and its constituent companies as well as the Board of Estimates and Apportionment, the Board of Transportation and the contractors there is a realization that patience and diplomacy are required to accomplish a result that everyone thinks is the right one.

MR. BONIFACE: In the construction of Section 1, Route 38, just as a matter of interest to you, we had to restore some 10-inch main and when we dug it up it was the old Scotch pipe. It was dated 1864. I should like to say that that pipe was just as good when we pulled it up in 1916 as it was apparently when it was put in. Mr. Ridgway showed on one of his plans what they call the preliminary drawings, showing the sub-surface structures. I think the Water Department and in fact all the public utilities departments ought to thank the subway construction division because it, at least, has given us a chance to get the proper plotting of all the sub-surface structures, so that their records were corrected once and for all. We did not find the mains as they were shown originally on the drawings. Now we know where they are.

A. E. HANSEN:[5] You showed a very interesting picture of the Eighth Avenue new double-deck subway, if I recollect, with 42- or 48-inch cast iron sewers suspended between the upper and lower levels. The question in my mind is how are we going to run our house sewers from the buildings to those sewers?

[5] Hydraulic and Sanitary Engineer, New York, N. Y.

ROBERT RIDGWAY:[2] There are service sewers paralleling the subway. The cast iron sewers referred to by Mr. Hansen are part of the trunk, that is, the three pipes carry the large trunk sewer across the subway. There will be no trouble about the house services as they are connected to the service sewers.

Speaking of the Scotch pipe to which Mr. Boniface referred, in building the original subway about 1902, we had to move a 48-inch main that was on Forty-Second Street, and replace it with a new 48-inch main on Fortieth Street. The old main was in the way of the contractor and as acetylene torches were not available in those days, and as he had difficulty breaking up the pipe with sledges, he hit upon the idea of putting jacks in the main and expanding the pipe until it broke. The horizontal diameter increased, as I remember it, more than 2 inches before any cracks appeared in the pipe.

ALEXANDER POTTER:[4] I should like to ask Mr. Ridgway, has there been any trouble with those siphons that were built under the subway, and are there many of them?

ROBERT RIDGWAY:[2] When somebody drops a featherbed down the manhole and it chokes the inlets there is difficulty with the siphon, but ordinarily it works very well. The design takes care of the sanitary flow with a small pipe and the storm flow with two larger ones, usually of cast iron, but sometimes of reinforced concrete. I hear very few complaints about them. There are a dozen or more of them if I remember correctly.

CHARGES FOR PUBLIC FIRE PROTECTION[1]

By R. L. Dobbin[2]

This is a subject that has been discussed many times before this Association, and it is probable that it will be discussed many times again. One of the best and most authoritative papers on the subject was presented by Metcalf, Kuichling and Hawley at the Rochester Convention of the American Water Works Association in 1911. There was also another of great value given by John Alvord at the Philadelphia Convention in 1914.

There is also a very interesting chapter in the "Manual of Waterworks Practice" on this subject, which it covers very completely.

However, I feel that the method of calculating the proper amount to be charged for public fire protection can be explained in a little more detail, and there are also other points on which my opinion differs from that of the authors.

The real problem that underlies the question of reasonable return for public fire protection involves a determination of the equitable distribution of the charges for water works service among the various classes of users.

A water works system has usually two sources of revenue, first, from public fire protection service, and, secondly, from domestic service, which latter includes industrial and public uses. It is with the first of these sources that this paper will deal.

The usual method for the determination of reasonable return for public hydrant or fire protection is an annual rental per hydrant. This rental is generally fixed by considering the average rates paid by other cities nearby, and rarely has any logical basis for its calculation.

When the return for public fire service is inadequate, the domestic consumer must make up the deficit. The entire community derives the benefit from adequate fire protection and the cost of it should be charged to the whole ratepaying population.

The individual ratepayer should pay for fire protection in proportion to the value of the property protected and not according to the amount of water he uses, or the fixtures in his house. Where the proper charge is made for public fire protection it is collected in the general tax, and each ratepayer pays his share according to his assessment.

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[1] Presented before the Canadian Section meeting, March 4, 1927.

[2] Manager, Public Utilities Commission, Peterborough, Ont.

An increase in charges to the city for fire protection service does not necessarily mean an increase in the gross earnings in all cases. In a great many cases it will mean a decrease in the domestic rate.

One method of ascertaining the proper charge for fire protection will be outlined in the following paragraphs.

The various items of capital must first be divided between the two main services, and the first to be considered is the distribution system.

DISTRIBUTION SYSTEM

The proper way to make this division is first to make a study of the value of a theoretical system sufficient in capacity for fire alone. Next, make a study of the value of a theoretical system sufficient in capacity for domestic service alone. The sum of these two values will give a value greater than the value of the existing system, and the value of the latter should then be divided between the fire service and domestic service in proportion to the theoretical values calculated in each case.

The value of all service pipes and meters will of course be charged directly to domestic service, and the value of all fire hydrants to fire protection service.

PUMPING EQUIPMENT AND STORAGE

The items of capital should be divided according to the capacity required. The capacity required for fire protection service can best be ascertained by enquiry from the Canadian Fire Underwriters Association.

With regard to capacity required for domestic use, this will depend to a large extent on local conditions. If you have an elevated tank or storage reservoir to supply part of the extra demand at the time of the peak, you will not require such a large capacity in the pumps as the system would which is pumping directly into the mains with no storage.

In the former case, the maximum day's pumpage, plus 50 per cent, is usually employed. In the latter case the maximum hourly rate of pumpage, plus 50 per cent, should be taken.

Add these two capacities together and find what proportion the capacities for fire protection and domestic service are of the total.

TABLE 1

Division of fixed and operating charges, City of Peterborough

ITEM	TOTAL AMOUNT	DIVISION OF CAPITAL			
		Domestic service		Fire service	
		Per cent	Amount	Per cent	Amount
Mains	$361,417.00	45	$162,500.00	55	$198,917.00
Services and meters	74,116.00	100	74,116.00	....	....
Pumping equipment	232,320.00	60	139,391.00	40	92,929.00
Buildings	37,478.00	75	28,100.00	25	9,378.00
Office equipment	1,609.00	100	1,609.00	....	....
Miscellaneous	2,878.00	100	2,878.00	....	....
Totals	$709,818.00	57½	$408,594.00	42½	$301,224.00

ITEM	TOTAL AMOUNT	DIVISION OF OPERATING EXPENSES INCLUDING ALL FIXED CHARGES			
		Domestic service		Fire service	
		Per cent	Amount	Per cent	Amount
Mains	$28,303.00	45	$12,736.00	55	$15,567.00
Services and meters	8,788.00	100	8,788.00	....	....
Pumping equipment	24,455.00	60	14,673.00	40	9,782.00
Building	2,749.00	75	2,062.00	25	687.00
Billing and collecting	4,160.00	100	4,160.00	....	....
General supervision	6,000.00	57½	3,450.00	42½	2,550.00
Miscellaneous	3,460.00	100	3,460.00	....	....
Totals	$77,915.00	63	$49,329.00	37	$28,586.00

The capital in the pumping equipment and storage will then be divided according to their proportions.

DISTRIBUTION FOR BUILDINGS

In determining the distribution of value with regard to buildings, the proportions should be about as shown in tables 1 and 2.

1. For all buildings not contributory to the pumping of water, 100 per cent shall be charged to domestic service.

2. For all buildings contributory to the pumping of water, 75 per cent shall be charged to domestic service and 25 per cent to fire protection.

TABLE 2

Statement of operating expenses of the Water Works Department for the year 1925, as it affects the charge to the City of Peterborough for fire protection for 1926

Maintenance and operation	$34,422.62	
Fixed charges	50,684.60	
Total	$85,107.22	
Less 315 hydrants at $10.00	3,150.00	
	$81,957.22	
City percentage, 33⅓		$27,319.07
Plus service charge on hydrants		3,150.00
Total charge to city		$30,469.07

Since this method was established, the City has paid as follows for fire protection:

YEAR	AMOUNT	NUMBER OF HYDRANTS	AVERAGE PER HYDRANT	AVERAGE PER CAPITA
1921	$23,062.30	293	$78.50	$1.08
1922	25,453.41	297	91.00	1.18
1923	26,815.18	300	89.00	1.24
1924	26,448.23	309	85.50	1.22
1925	28,940.93	311	93.00	1.34
1926	30,469.07	315	97.00	1.41

OPERATING EXPENSES

Now that the above percentages have been determined, we shall proceed to divide the expenses between the two services.

It is, of course, understood that no part of a filtration plant or other purification works is considered in this analysis. The capital charges and operation and maintenance expenses for this portion of a water works system should be charged directly to domestic service.

Operation and maintenance of mains should be divided on the percentages found for the distribution system, as also the fixed charges, such as interest and sinking fund and depreciation, etc., the latter, however, pertaining only to the distribution system.

Operation and maintenance of services and meters, together with the fixed charges on these, should all be charged to the domestic service.

The operation and maintenance of pumping equipment, together with the fixed charges, should be divided according to the percentage found for the capital charges, and similarly with the upkeep of buildings.

The cost of billing and collecting should be all charged to domestic service.

General expense and supervision should be divided according to the proportion of the total capital in each case.

The above is a brief outline of the procedure necessary to calculate the proportion of the annual cost chargeable to domestic service and fire protection.

To illustrate how it works out, I will give the values found for the city of Peterborough, made in 1921, in table 1.

Metcalf, Kuichling and Hawley deduced the following formula, in which y is the percentage of the total capital cost of a water works system which should be charged to fire protection, and x is the population in thousands:

$$y = \frac{147}{x^{0.31}} - 12.1$$

This works out in Peterborough in 1921 as about 45 per cent, which figure agrees very well with that found by investigation.

The statement is also made in that paper, that the cost of the portion of the water works plant involved by fire protection service, probably constituted from 60 to 80 per cent of the entire cost of the physical property in the case of communities having less than 5,000 population, 20 to 30 per cent in communities of 100,000 population, and perhaps 10 to 20 per cent in the case of our largest cities.

This statement is borne out by subsequent investigations as noted in the "Manual."

CHARGING FOR FIRE PROTECTION

The Manual gives three general methods of determing the annual charge for fire protection service, as follows:

1. Hydrant rental.
2. Charge per mile of pipe, with an allowance per hydrant for maintenance.
3. Charge per inch-foot of pipe distribution system, with allowance per hydrant.

To these I would like to add a "percentage of annual cost" method which I will explain later.

The first of these methods is the oldest and, as I said at the opening of this paper, is not logical.

For one thing the value of fire protection is in no way proportional the number of hydrants and it also tends to keep down the number installed.

The second method is better than the first, because it takes into consideration, to some extent, the size of the system, and would permit of increase, proportionately as the system expanded. But it does not take into consideration the sizes of the pipes.

This is where the third method is superior. The number of "inch-foot" units is determined by multiplying the linear feet of pipe of each diameter by the diameter in inches.

The annual charge per hydrant is based upon the average annual cost of operating, maintaining and repairing the hydrants.

Many charges of this latter type have been established in the United States, varying from $2.25 to 76 cents per inch-foot, and averaging about $1.23.

On this basis of charge, Peterborough would be rated at $1.31 per inch-foot for 1921.

The inch-foot system has the advantage that the total charge is in proportion to the pipe capacity as well as to the number of hydrants. But the true cost also depends on other features of the plant of which this system of charging does not take cognizance. Then, too, the city might object to laying the larger sized mains as this would directly increase their cost. The capacity and cost of a main, in addition, do not vary directly with the diameter.

The fourth method, which is not included in the "Manual's" list, may be called the "Percentage of Annual Cost" and is the one adopted in Peterborough.

Based on the results as shown in table 1, we decided to charge one-third of the annual expense of running the water works system, exclusive of filtration, to fire protection, and have so billed the city each year.

We, however, did not wish to base the charge entirely as above, but thought it wise to make it in the following form:

A certain small part of the cost of fire protection is proportional to the number of hydrants, that is, the investment in the hydrant itself and its maintenance. Our system of bookkeeping did not show the investment in the hydrants as separate from the mains, but we estimated this to be, on an average, $100 each. The fixed charges on this sum amount to about $7.50, and we estimated that maintenance would average $2.50, therefore we put the total annual cost per hydrant at $10.

TABLE 3

Amounts paid for fire protection in 1926 by cities in Canada

CITY	POPULATION	TOTAL COST OF UPKEEP	NUMBER OF HYDRANTS	FIRE PROTECTION CHARGES			
				Total amount collected	Rental per hydrant	Per cent total upkeep	Per capita
Toronto	525,000	*	7,190	964,818		36.6	$1.84
Montreal	568,000	$2,284,329	3,401	None	None	None	
Winnipeg	197,000	997,911	2,757	76,470	30	7.7	0.39
Ottawa	127,100	514,529	1,565	None	None	None	
Quebec	125,000	425,000	1,200	None	None	None	
Hamilton	123,395	542,938	2,262	20,000		3.7	0.16
London	67,000	269,093	1,066	19,188	18	7.1	0.29
Edmonton	65,000	487,264	910	40,507	45	8.3	0.62
Regina	40,000	246,152	576	43,037	75	17.5	1.08
Brantford	27,739	*	424	23,320	55	*	0.84
Walkerville	27,000	*	440	15,464	65/35	*	0.57
St. Catherines	26,000	65,505	474	9,480	20	14.4	0.37
Kitchener	25,856	100,304	370	13,658	35	13.6	0.53
Peterborough	21,519	85,107	315	30,469		33.3	1.41
Niagara Falls	20,000	76,480	297	8,900	30	11.6	0.45
Stratford	19,000	59,855	271	8,979	40/30	15.0	0.47
St. Thomas	17,000	78,043	218	12,750	60	16.3	0.75
Chatham	15,000	51,000	240	9,600	40	18.8	0.64
Woodstock	10,000	38,961	185	6,475	35	16.6	0.65
Orilla	8,000	43,266	143	5,362	37½	12.4	0.68
New Toronto	5,023	75,000	98	2,450	25	3.3	0.49

* Not given.

So we charge the city a straight $10 per hydrant, subtract this amount from the total cost of operating, and charge the city one-third of the balance.

For illustration, in table 2 the details of our billl to the city for 1926 are given. I might say here that the charge for a certain year is based on the expenses for the preceding year.

By this method, the total charge is increased in proportion to the growth of the system. If a large main is laid, the annual cost will be increased more than if a smaller one were laid, and consequently the charge for fire protection is increased. Also, if other parts of the system are increased, a part of the annual cost goes into the fire protection charge.

In order to ascertain the situation in Ontario, with regard to this subject, a questionnaire was sent out to about twenty municipalities and the information received was listed in table 3.

This table shows that there is a wide variation in the amounts charged for fire protection. Two cities in the list, Toronto and Peterborough, are on a percentage basis, the former charging 36.6 per cent of the annual expense, and the latter 33⅓ per cent.

Three of the cities, Montreal, Quebec and Ottawa, charge nothing at all.

Leaving out those cities which charge on a percentage basis and also those in which nothing is charged, the weighted averages are as follows:

Hydrant rental	$29.40
Per cent of annual expense	8.5
Per capita, dollars	0.46

It is apparent from these figures, that nearly all the cities listed in table 3 are not charging enough for public fire protection.

DISCUSSION

E. V. Buchanan: I would like to compliment Mr. Dobbin on his excellent paper on "Fire Protection Charges." No doubt from a purely theoretical standpoint, Mr. Dobbin's method of obtaining the proportion for the cost of domestic service and fire protection is correct, but I am inclined to think that, where city councils have to be dealt with, the argument is somewhat unconvincing.

There is no doubt that there are municipalities whose system is no more adequate than necessary for domestic requirements and yet, because of local conditions, may be quite suitable for fire-protection purposes.

In recent years fire departments have gone through a period of rapid changes. The horse-drawn hose reels have given place to motor trucks and high-powered pumping units. Also water is not the only weapon of the fire department, but extinguishers and chemicals play an important part, so that the function of the water works department is not so great as formerly.

I think that it is generally accepted that the first duty of the water works department is that of supplying water for domestic, sanitary and industrial uses; and secondly, for fire protection. If that is so, then the municipality as a customer for fire protection service may be looked upon as one to whom a by-product, so to speak, may be sold.

If we look at the problem from this point of view, the division of costs will be entirely different. First, all costs that are specifically incurred for fire protection could be computed. These might be fire hydrants, fire pumps in pumping stations, and additional reservoirs necessary under the Fire Underwriters' regulations. Then there would be the cost of the increased size of mains necessary because of the fire-protection service. The extra cost of maintenance, operation and overhead could be arrived at, and so a total cost would be obtained which would be much less than that derived by Mr. Dobbin by laying out two hypothetical systems.

Following out a method of this kind, I have roughly arrived at a figure of 20 per cent. Although this is much lower than the figure worked out by Mr. Dobbin, it is still greatly in excess of the charges made by Canadian cities, with the exception of Toronto.

When we, as water works men, are making analyses such as these to see if we are getting our "pound of flesh," it may be well to consider the question which has been raised time and again, namely, "Should publicly-owned utilities pay taxes on the same basis as private corporations?" It has never seemed to me that there is any logical argument against such a proceeding, and as taxes charged by the city against the water works department would have to be distributed over the consumers by increase of the water rates, and on the other hand as fire-protection charges made to the city by the water works department have to be divided among the taxpayers, these two charges could be placed against one another on an even basis for cancellation.

I admit, however, that the taxes on a water works system should not amount to much more than 5 to 10 per cent of the gross expenditures.

The basis of the paper is the distinction which is made between the taxpayer and the water consumer. Let us consider for a moment the responsibility of the water consumer to the taxpayer. The water consumer demands of the taxpayer—represented by the corporation—that an adequate supply of water be furnished. The taxpayer says that he has not the money necessary to do what is asked without borrowing it, and he is told by the water consumer to borrow it then, and so Mr. Taxpayer agrees, but he is entitled to some consideration for mortgaging his property for the benefit of the water consumer, and so should obtain a service to protect his mortgaged property at a very minimum of cost.

It is desirable in our modern municipalities to keep the tax rate as low as possible, and so avoid keeping people away through fear of a high tax rate. Therefore, we should spread out as much as possible, and over as many objects as possible, the charges required to provide the modern conveniences and necessities; so let the water consumer pay all the items that can be logically charged against him. Might I venture to suggest that the raising of a fire-protection charge may be prompted in some cases by a desire to dodge the unpleasantness of raising the water rates to the water consumers?

The point which I wish to make is that, as a matter of good business policy, the water works department should demand not more than about 15 to 20 per cent of the total cost as a fire-protection charge.

With regard to the method of assessing the fire protection charge, I am in favor of some combination system such as charge No. 3 mentioned by Mr. Dobbin, namely, "charge per inch-foot of pipe distribution system," with an allowance for maintenance of each hydrant. I do not believe that there can be much objection to this method, as the necessary number of hydrants and size of mains can be easily determined, and should not be objected to by any reasonable council on the plea of economy. If the method of assessing as recommended by Mr. Dobbin is approved, then I believe that the actual percentage of cost should be worked out each year to determine the bill. The fact that the figure arrived at in 1921 in Peterboro was 33⅓ per cent does not mean that the percentage for 1927 will be 33⅓ per cent.

After having worked out the cost for fire protection by some predetermined method, the allocation of this cost could be made, let us say, for method No. 3, namely, "per inch-foot of distribution system," and per hydrant, and the unit charges so derived used for a period of years. The total charges would grow with the system in a more equitable proportion than "the percentage of annual cost method."

The tables bring out very strikingly that the charges for fire protection are not adequate.

Mr. Dobbin has rendered a valuable service to water works men in presenting this excellent paper, which is well worth a close study not only by water commissioners but also members of city councils.

G. F. Lewis: The discussion of Mr. Dobbin's paper on "Fire Protection Charges" opens up so many channels that it is difficult to dispose of it in a few words.

The lack of uniformity—or basis for such charges—is summed up in Mr. Dobbin's own words when he says, "This rental is generally fixed by considering the average rates paid by other cities nearby, and rarely has any logical basis for its calculation."

I cannot agree with Mr. Dobbin when he says that the individual ratepayer should pay in proportion to the value of the property, and not according to the amount of water he uses, or the fixtures in his house.

To my mind there is neither equity nor justice in this plan. The carrying out of such a policy would penalize the manufacturer, who uses practically no water in making his finished product, for the benefit of the manufacturer whose finished product depends almost entirely on the treatment and use of enormous quantities of water before it can be marketed.

Mr. Dobbin further argues that an increase in charges for fire protection service will mean a decrease in the domestic rate. Again we have an incongruous condition presented, for statistics show that two out of every three fires occur in dwellings. One fire, however, in a large manufacturing plant may use up as much water as all the fires in dwellings in the town do in an entire year; again throwing any set formula out of gear.

The strongest argument against the excessive charges made for municipal fire protection is the fact that in laying out a water works system, adequate fire protection is the last thing considered.

It has been the practice of municipal officials to provide water primarily for domestic service on a revenue-producing basis, secondly for sanitary purposes, thirdly for industrial use, fourthly for public service, and fifth and lastly for fire fighting purposes. Notwithstanding the installation of a large percentage of 4-inch mains—which are not standard for fire-fighting purposes—engineers are aware that large quantities of water must be readily available for the purpose of extinguishing extensive fires. With fire protection first, all the other requirements would be amply supplied.

I cannot see the object "in making a study of the value of a theoretical system sufficient in capacity for fire alone," if that system be not actually installed. Nor is the suggestion practical of asking the C. F. U. A. for "the capacity required for fire-protection service" for the purpose of charging the full amount of such service as fire protection, as the great majority of municipalities are deficient in their pumpage or reservoir capacity.

I do not agree with the statement that "the value of fire protection is in no way proportional to the number of hydrants," for the number of hydrants is most certainly proportional to fire protection.

The tables compiled by Mr. Dobbin are very interesting, but in addition to the fire protection charges, which run from 16 cents per capita in Hamilton to $1.41 per capita in Peterboro and $1.84 per capita in Toronto, it would have been very illuminating to know the water rates charged to consumers in the 21 municipalities under review.

Naturally in cities like Toronto and Peterboro, where charges per hydrant amount to $154.19 and $96.72 respectively, the water rates charged to consumers should be correspondingly low, and, of course, the deficit or difference is included in the taxpayers' bills under the cover of fire protection.

Independent or privately-owned water works systems do not find it necessary to make any such high charges for fire protection. If they did, the citizens would soon rise in protest.

Three cities—Montreal, Ottawa and Quebec—absorb the cost of fire protection in the rates charged to consumers. London charges at the rate of $18 per hydrant per year for fire protection, and makes money on its water works system.

I know a town where the annual charge for water for fire protection purposes exceeds the amount of their annual fire losses. In that case, water would appear to be somewhat of a luxury.

Fundamentally the entire question is really a matter of bookkeeping, for the citizens must pay the bill.

The idea evidently is in some cases to charge as much as possible to the fire department, to be liquidated by the citizens in their tax bills, so that water rates may appear to be kept down.

I think that the members of the American Water Works Association could easily work out a uniform standard of distributing costs which would be much more satisfactory than the systems now in vogue.

N. R. Wilson: I am sure we are all in agreement that this is a very excellent paper, and that Mr. Dobbin has evidently made an exhaustive study of the subject. I agree that you have to get a theoretical basis to start with in regard to the distribution system. You do not have to use the same class of pipe for a domestic service that you would have to use for a fire service.

You have to have pumps for the domestic service, but 40-lb. pressure would be ample. But for the fire service they have to run up to 110 or 120-lb. pressure. Therefore, unless you have some theoretical basis to act on, you cannot begin anywhere.

I cannot agree with Mr. Dobbin that no part of the filtration plant should be charged to fire protection. Where you have filtration, all the water that is used for fire purposes has to pass through the filtration beds. You have to increase the capacity of the filtration plant in order to cover fire service.

T. H. Hooper: I cannot help but think that Mr. Dobbin's paper is more or less based on the town of Peterborough. Naturally he has worked it up from his day-to-day work in his own town. Conditions in this Dominion vary so much that it would be extremely hard to arrive at a rule that would apply to all places. In Winnipeg we figure that $30 per year is a fair charge for a hydrant. See what we give for that: We have to maintain these hydrants; every time that a hydrant is used during the winter months it has to be repacked, and the work has to be done as quickly as possible, because the fire might break out a second time. We put on as many as twenty and thirty inspectors, and in the down-town district we inspect the hydrants frequently, and in other parts of the town once a month. Once a hydrant is packed in the fall, I think the best thing is to leave it alone unless there is a leak. Constant inspection often sets up small leaks. We have a high-pressure system in Winnipeg, and we can pump up to as high as 300-pound pressure. That system is confined to the wholesale district and that district is charged with the maintenance, and the principal and interest is charged to the city as a whole.

I hope that we will have as interesting a paper on this subject next year, and that it will be put on early, so that we can have more time to digest it.

Wm. Gore: Mr. Dobbin has adopted a scientific method for calculating the cost of fire service. There appear to be three different scientific methods of the type he has adopted: One is to assume that the whole city is laid out for domestic water works purposes, and the estimate the cost of adding on the fire service; that would give a certain figure. Another method is to assume that the water works is laid out primarily for fire service, and then estimate the cost of the domestic service in addition to that. The third method is to estimate it as a partnership affair, and I believe that is what Mr. Dobbin has done.

W. C. MILLER: In discussing Mr. Dobbin's paper I should first point out that it is a type of paper that should be presented at a convention of municipal officials who are not exclusively interested in water works.

Mr. Dobbin's conclusions are marshalled very plainly and effectively, and there would be no difficulty in maintaining them in the face of any possible discussion presented from the point of view of the official who represents that phase of the public entity concerned with paying for fire protection by a mill rate on his assessment.

The question of charges for public fire protection is a live one, for most plant managers who are not in the fortunate position of Mr. Dobbin, whose plant receives an equitable revenue from such service. The writer finds that among those plant managers with whom he has discussed the question personally, the rate for public fire protection is arrived at usually by means of a compromise between the Water Board and the City Council, on the assumption that the City Council, representing the department called upon to pay these charges, has as much to say in deciding what this rate should be as has the Water Board, and that in the final analysis the City Council must be agreeable to the rate struck before it can be collected from them. The result of this attitude is quite plainly seen in Mr. Dobbin's table 3, where the percentage of total revenue received from fire protection is practically only a nominal one in many cases.

I should like to ask Mr. Dobbin whether, in arranging for this charge in Peterborough, it was the stand of his board that the final decision in the matter rested with his board or with the council; and if there was any question as to who had jurisdiction in the matter, what statute authority, if any, justified the final action.

In St. Thomas we have made a separation of the present capital charges of the various parts of our plant, having to do with fire protection, as follows:

	TOTAL VALUE	PER CENT TO FIRE PROTECTION	TOTAL VALUE FOR FIRE PROTECTION
Mains	$373,695	65.5	$245,000
Fire hydrants	14,338	100.0	14,338
Pumps	45,000	81.6	36,750
Pump house	17,250	25.0	4,300
Elevated water tower	222,057	0	
Services			
Meters			
Filtration plant			
	$672,340	44.7	$300,388

Including suburban consumers, this plant supplies about 18,000 people. Metcalf, Kuichling and Hawley's formula for a population of 18,000 gives the percentage as 47.9 per cent.

In these figures construction for storage is not included. It would obviously be difficult to strike a comparable percentage if such works were included, since, to take an extreme case like that of St. Thomas, approximately 25 per cent of the total capitalization is involved in works for the collection of water from a small watershed, while another plant might have a supply works consisting of wells, or, if situated close to a body of water, simply an intake, the cost of which would be a very small proportion of the total capitalization.

These figures are submitted simply as evidence of another plant that has been analyzed, and the proportions of which, as segregated between fire protection and domestic service, follow substantially Metcalf, Kuichling and Hawley's formula, as quoted by Mr. Dobbin.

In many plants the practice is followed of paying as they go for certain normal annual capital expenditures, covering such things as meters, services and small main extensions, which expenditures provide for the normal expansion of the business, any abnormal extension being taken care of by the issue of debentures.

In a case of this kind, covering only these normal extensions, would Mr. Dobbin use the cost of these extensions as affecting the "percentage of annual cost" rate, or would he apply the previously calculated percentage to the cost of these normal extensions and include this in his bill for fire protection, with the correct proportion of the cost of operation and maintenance, based on his revenue and expense sheet?

For the purpose of bringing Mr. Dobbin's table 3 up to date, I would point out that, in the case of St. Thomas, since this table was compiled, the hydrant rental charge has been increased to $80, thus making the total amount collected $17,440 per annum, this being 22.3 per cent of the total upkeep, or $1.03 per capita.

I had hoped that Mr. Dobbin might have touched on the question of private fire-protection charges, which topic is coming to the fore more and more each year with the promotion of automatic-sprinkler systems.

W. L. McFaul: I have been greatly interested in Mr. Dobbin's paper and I am sure that he has given us a great deal of matter for study. The conclusions that he has arrived at are no doubt quite in accord with his system. I must say that the conditions of financing water works where the commission is independent of the city council are slightly different from a financial undertaking where the municipal system is directly under the control of the council. Broadly speaking, in a city such as Hamilton, I would say that 10 per cent of the gross revenue of the water works would be ample to charge for fire purposes. That is certainly more than we get at the present time. It would be an outside figure, taking into account every consideration.

A. U. Sanderson: Mr. Dobbin uses the same system that we use in Toronto, and as a representative from the only other city using the same system that he does, I would like to say a few words. Mr. Gore's analysis of the scientific lines on which the subject should be approached seems to put the situation very clearly. If, like Mr. Lewis, you are representing the fire interests, and look at the matter from the point of view of the fire protection that the taxpayer receives because the water works was there first, then you could make out a very good case. Mr. Lewis and Mr. Buchanan did make out a very good case. It appears to me that both these gentlemen were influenced in their attitude of mind towards the question. I am sure that Mr. Buchanan could make out a very good case for his high service charge in London. We could argue this case all night, pro and con, but if it is argued from a scientific point of view I think that it would be very hard to make a case against Mr. Dobbin's paper, which is really a scientific system of charging for fire protection.

R. L. Dobbin: The discussion has been very interesting. Most of the gentlemen said very nice things about the paper. The greatest compliment, I think, is the discussion that took place. This paper was designed in the first place to show what my opinion was as to the proper method of designing a charge for fire protection, but most of all it was designed to bring out some discussion, and I think that you will admit that it had that effect.

I left a number of loop-holes, which Mr. Lewis promptly found, as did also some of the other speakers. I have not prepared any direct answer to them. In London apparently they are short $35,000 which they should get from the city. That is only 50 cents per capita and would not make any difference in the London taxes, which I understand are high.

Mr. Buchanan brought out the point that we should adjust these rates each year. As a matter of fact, we should adjust them every time that we put in a new main. With us the adjustment is made every ten years. I made an analysis of our system, and for last year there was very little difference in the charge; it was 37 per cent in the first analysis in 1921, and last year it was just about the same.

The question brought up by Mr. Miller was as to what authority we have to charge these rates. At the time that we put this rate in operation, Mr. Gordon, a prominent lawyer in Peterboro, attended the meeting, and had with him two or three law books, and he looked at us, like a judge, while we were making our statement, and then he said, "We do not have to pay it." We replied that the public utility commission was given power to make rates, and we considered the fire-protection charge as a rate. He looked at his law books and said, "I guess you are right," and the charge stood.

We passed the by-law for ten years, and we consider that we scored a considerable victory, for Mr. Gordon was there for the purpose of telling us where to get off. You will find the public utilities act will allow you to make a proper rate. In Toronto the water works is run by the city council, and they must have some way of inducing the city council to charge the proper amount for public fire protection.

G. F. Lewis: Are you building up a surplus by these charges?

R. L. Dobbin: Under our act we are allowed to keep a certain amount as a surplus. That surplus has now come up to the point which we cannot keep any more, and we are turning it back to the city.

C. J. Pratt: Did you cut down your ordinary water rates when you adopted these excessive hydrant charges?

R. L. Dobbin: The answer to that is that we are putting in a new filter plant.

E. V. Buchanan: I am afraid that my remarks were rather rambling. Mr. Gore claims that this sytem has some scientific basis. Assuming that the water works sytem was put in for domestic purposes, it would be proper to calculate the extra amount necessary to provide fire protection. I do think that water consumers owe something to the taxpayers who provided the money for building the water works.

A. U. Sanderson: The city of London provided the money, but the water works provides the interest on the debentures and retires them when due.

E. V. Buchanan: The rural customer on the "Hydro" makes the statement that the city does not pay; that the province of Ontario puts up the money and that the province of Ontario owns the Hydro system; and he claims that the man in the rural community is entitled to some consideration on that account. I do not see why that same principle is not justified in this case. No water works that I know of is paying taxes, and I do not believe that any logical argument can be advanced as to why a water works system should not pay taxes.

T. H. Hooper: We pay taxes in the city of Winnipeg.

A. U. Sanderson: When the Dominion Government guaranteed the bonds of the railway companies, both the C.N.R. and the C.P.R., they did not become the owners of the railways and finally they had to buy one of them.

T. R. Logan: Our water works system pays taxes the same as every other taxpayer, and we make everybody pay for the water they use.

T. Hodkinson: Mr. Dobbin said that he had 315 hydrants; and how many miles of mains?

R. L. Dobbin: Fifty. The city council have control of placing the hydrants, and that is the reason that we make the ten-dollar charge, so that if they want an abnormal number of hydrants, they will have to pay for them.

The Chairman: One point has been overlooked in this discussion: The mains are not extended to all parts of the municipalities, and these sections would not have any fire protection and, yet with the charge that Mr. Dobbin is making, the taxpayer would be paying for fire protection that he was not getting.

R. L. Dobbin: I want to express my thanks to those members of the association who answered my questionnaire and gave me the information that I required. I would like these members to go back with my paper and try to figure out what the percentage should be. Then, with your permission, I would like to collect that information a year from now, and make out another table and show the results. Probably we might have some discussion on this subject at our next meeting. It might be possible to have a debate on the subject.

C. R. Cole: I represent a municipality of 50,000 population. We have 1,600 hydrants. The majority of our mains are put in under the local improvement plant. We have nothing less than 16-inch mains, and we install a hydrant every 300 feet, and the people on the street pay for them.

N. R. Wilson: Brantford pays taxes on the pumping station and all buildings.

W. C. Smith: So much per hydrant as the basis of the charge for fire protection is rather peculiar. Water works constitute 35 per cent of the total credit allowed municipalities for fire protection. It is allowed equal credit with the fire department. That shows that they put the water works department on as important a footing as the fire department. If the fire department costs $25,000 a year, should not the city pay a similar amount for the other branch of protection, the water works?

Speaking on annual charges for hydrants, I think it has a very strong tendency to make the city conserve on the number of hydrants. Would it not be better to select a certain proportion of the total of fixed charges and operating costs for each year, which for a small community of 10,000 people would be a much higher ratio than for a city of 50,000? I think that, in Mr. Buchanan's city of 65,000 people, it would be a much smaller proportion of the whole than it would be in Mr. Dobbin's municipality. As a matter of fact, I think that the basis of charge should be struck for various types of municipalities, and should be more upon the number of mains installed in the municipality.

In my city we have analyzed this thing carefully in an effort to get more money from the city. We are now getting, on behalf of fire protection, 6½ per cent of our total fixed and operating charges, which I contend is less than one-quarter of what we should get for that service. It is difficult to have any change made, but we have given the city notice that on the first of January, 1928, the rate of hydrant rental will be increased 25 per cent, making the rate $60. Tenants occupy 45 per cent of the buildings in the city, and they are paying for the fire protection. We have a bank building, say worth $100,000, where they use water equivalent to a small householder. The bank pays nothing for fire protection, unless they pay for it through the medium of the tax rate. The taxpayers are now paying a greater ratio, but not a sufficient ratio, because the small householder pays a much higher rate on the small quantity of water used.

EXPERIMENTS IN THE HYDRAULICS OF FILTER UNDERDRAINS

By N. Malishewsky[1]

The lateral underdrains of rapid sand filters at present generally consist of perforated pipes or tubes, the perforations being of the same diameter equally spaced. When washing a filter the underdrains must supply water as uniformly as possible. For this purpose it is necessary that the head in the perforated laterals should be equal over their entire length. Due to the movement of water through the lateral, head is lost by friction. Therefore, it would seem that the head at the end of a lateral would be less than at its entrance, but by the gradual reduction of velocity of flow in a perforated lateral it is assumed that the velocity-head $\frac{V^2}{2g}$ will increase and, due to this, the head toward the end must tend to increase. In order to explain the result of the apparent reciprocal action of these two opposite tendencies, the author together with Professor G. T. Proskura undertook the experiments described later, in the laboratory of the Technological Institute of Kharkow.

THE EXPERIMENTAL DETERMINATION OF HEAD IN LATERALS 2 INCHES IN DIAMETER

Figure 1 indicates the arrangement of piping used during the experiments. A - B is a lateral 2-inches in diameter with 40 orifices, each 5.5 mm. in diameter, 20 orifices are on each side, equally spaced between points C and B, and the tube between A and C is unperforated. The distances between the points A, B, C, and D are shown on the figure. The end of the lateral at B is closed. Water is forced through it by a pump, passing from A to C and then out through the orifices on either side of the lateral between the points C and B.

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[1] Professor of Hydraulics, Technological Institute of Kharkow, Russia.

FIRST EXPERIMENT

In the first set of experiments, October 21, 1926, a quantity of water equal to 3.333 liters per second was tried. Five observations were made and the average observed water levels, recorded by piezometer tubes, are shown on figure 1, the water levels being measured from the top of the 2-inch lateral. The loss of head through the unperforated part of the lateral having a length of 2 meters is 173 mm. With a discharge equivalent to 3.333 liters per second the velocity in the 2-inch lateral is $\frac{3.333}{0.2027}$, or $V_1 = 1.64$ meters per second.

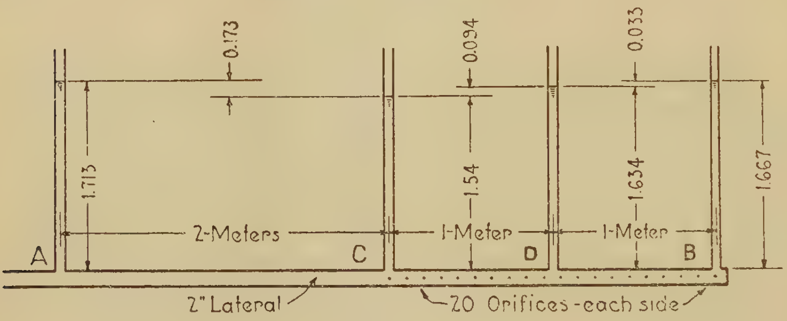

FIG. 1

TABLE 1

	OBSERVED HEAD	THEORETICAL VELOCITY-HEAD CORRESPONDING TO LOST VELOCITY	THEORETICAL LOSS OF HEAD BY FRICTION	OBSERVED LOSS OF HEAD BY FRICTION
	meters	*meters*	*meters*	*meters*
Difference of heads between C and D..	0.094	0.1025	0.0516	0.0085
Difference of heads between D and B..	0.033	0.0342	0.0061	0.0012

At point *D* the theoretical velocity will be equivalent to one-half of the above or $V_2 = 0.82$ meter per second. The velocity-head at point *C* is $\frac{V_1^2}{2g} = 0.1367$ meter, and at point *D* it is $\frac{V_2^2}{2g} = 0.0342$ meter. The difference of velocity-heads between the points *C* and *D* is $0.1367 - 0.0342 = 0.1025$ meter. The observed heads show the increase of pressure towards the end of the lateral to be almost equivalent to the lost velocity-head caused by the decrease of velocity from *C* to *B*. The friction losses in the perforated part of the lateral have very little influence upon the height of head. These facts are set forth in table 1.

The losses of head were calculated by the formula:

$$dh = \frac{K(Q + qx)\,dx}{d^5}; \qquad h = K\frac{l}{d^5}(Q_1 + 0.55\,Q_2)^2$$

The coefficient K is determined from the experiment of the loss of head in the unperforated part of the lateral between points *A* and *C* by means of the equation:

$$0.173 = K\,\frac{2(0.00333)^2}{(0.0508)^5}; \qquad K = 0.0027$$

The observed losses of head are 5 to 6 times less than the theoretical and this is the surprising phase of this phenomenon.

SECOND EXPERIMENT

On October 23, 1926, the experiment was repeated with $Q = 3.5$ liters per second and it was ascertained that between *A* and *C* there was a loss of head equivalent to 180 mm., between *C* and *D* there was an increase of head equivalent to 100 mm. and between *D* and *B*, 30 mm. The results obtained were almost identical with the foregoing, except the last value, 30 mm., which is somewhat smaller, due to the difficulty in obtaining measurements caused by fluctuations of the water level in the piezometer tube.

The area of one orifice 5.5 mm. in diameter is 23.75 sq. mm. The area of the 40 orifices is 950 sq. mm. The sectional area of the 2-inch diameter lateral is 20.268 sq. cm. The velocity of flow V in the lateral is 1.64 meters per second.

The velocity in orifices is: $1.64 \times \frac{20.26}{9.5} = 3.5$ meters per second.

Using the coefficient of throttling a water jet as 0.62 the effective velocity becomes $\frac{3.5}{0.62} = 5.63$ meters per second. The corresponding velocity-head $\frac{V^2}{2g} = \frac{31.6}{2 \times 9.81} = 1.61$ meters, which corresponds closely to the observed height of head.

THIRD EXPERIMENT

Another experiment was tried on October 23, 1926, with a smaller discharge, or $Q = 2.52$ liters per second. The observed heights of head are shown in figure 2, and the comparison between these and the theoretical are shown in table 2.

The velocity in the unperforated part of the lateral between A and C is $V_1 = \frac{2.52}{0.2027} = 1.243$ meters per second. At point D it is one-half of the above, or $V_2 = 0.621$. The velocity-head at point C is $\frac{V_1^2}{2g} = \frac{1.54}{2 \times 9.81} = 0.0784$ meter, and at point D it is $\frac{V_2^2}{2g} = 0.019$ meter, the difference being $0.0784 - 0.019 = 0.0594$ meter.

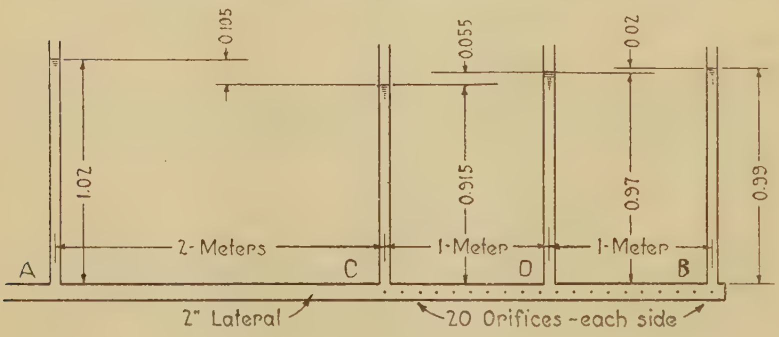

Fig. 2

TABLE 2

	OBSERVED HEAD	THEORETICAL VELOCITY-HEAD CORRESPONDING TO LOST VELOCITY	THEORETICAL LOSS OF HEAD BY FRICTION	OBSERVED LOSS OF HEAD BY FRICTION
	meters	*meters*	*meters*	*meters*
Difference of heads between C and D..	0.055	0.0594	0.0309	0.0044
Difference of heads between D and B..	0.020	0.019	0.0041	0.001

The discharge velocity through the orifices with $D = 5.5$ mm. is $V = 1.243 \times \frac{20.26}{9.5} = 2.64$ meters per second. The effective velocity is $\frac{2.64}{0.62} = 4.27$ meters per second. The corresponding velocity-head is $\frac{V^2}{2g} = \frac{18.2}{2 \times 9.81} = 0.93$ meter.

FOURTH EXPERIMENT

Another experiment was made on November 5, 1926, using the drainage system of the rapid sand filter of the Malinowskaia Station of the Kharkow Water Supply Board. The size of filter is 5.3 × 4.3 meters = 22.8 square meters. In the center of the filter, running lengthwise, is a 100 mm. diameter manifold with 22 branches or laterals, each 1½ inches in diameter, 11 to each side. During the experiment every other lateral on one side was closed, thereby leaving 12 in operation; 6 of these were on each side and the distance between the active ones was approximately 1 meter. Water was supplied through one end of the manifold, the other end being closed. The discharge was 60.5 liters per second or equivalent to a velocity at the beginning of the manifold of 7.66 meters per second. The velocity-head $\frac{V^2}{2g} = \frac{58.5}{2 \times 9.81} = 3.0$ meters. The observed heads, in meters, on the manifold were as follows:

At the beginning	2.12
1.85-meters from the beginning	3.44
At the end, or 5.1-meters from the beginning	4.14

The head at the end of the manifold appeared to be 2.02 meters higher than at the beginning. The friction loss was 3 − 2.02 = 1 meter. The loss of head as calculated by Gorbachew's formula is $\frac{5.5}{3} = 1.83$ meters. The loss is calculated on the basis of old tubes, whereas we had a new-asphalted cross-connection 4 inches by 1½ inches, but there were 10 bell and spigot joints in the distance of 5-meters.

CONCLUSIONS

1. The method of calculating the loss of head in wash water underdrains is not mathematically correct.

2. In the cases described above, the velocity-head shows a greater influence on distribution of water than the friction loss of head.

3. It may be possible to obtain an equal head along the entire lateral, by means of an artificial increase in the loss of head in the lateral in such a manner as to make it equal to the velocity-head.

To solve the last problem the laboratory of the Technological Institute of Kharkow is preparing to conduct some experiments. It seems that the most convenient type of filter for this purpose will be one having wooden laterals of rectangular section for underdrains.

A GENERAL RULE FOR MAKING EXTENSIONS

By R. E. Duffy[1]

Many persons engaged in, or whose duty it is to pass upon, the work of extending lines or mains to furnish service, such as electric, water or gas, to customers in new locations realize the wide differences in the rules by which various utilities will extend their distribution systems. The extension rule, as it is commonly called, of some utilities requires the customer to finance the extension by depositing with the utility the estimated cost of the extension less a fixed amount borne by the utility. The amount deposited by the customer may be a large or small portion of the entire cost depending upon the estimated cost. The utility agrees to rebate to the customer a fixed sum for each new customer served from the extension during the first three to five years following the extension, the total refund to be no greater than the amount deposited by the customer. Other utilities agree to rebate a certain per cent of the customer's bill during the first few years of the extension. Some have rules requiring the customer to pay for the entire cost of the extension and make no refund.

The cost of the extension under the above rules and many other similar ones is set up as fixed capital owned by the utility. The rates charged are generally those charged the other customers of the same class, but to whom the service has been furnished without a deposit or extension charge, having come within the allowable cost of extension for a new customer. If the distribution system of the utility is growing and extending rapidly so the extensions are absorbed into the general distribution system before replacement must be made no special note ordinarily is made of the replacement. The increased load may also have required replacement before it is required by depreciation. But the extending of electric lines to serve rural or farming customers is now bringing to the attention of some of the utilities the weakness of some of the extension rules. The lines were built sufficiently long ago to need replacement now.

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The original customer was allowed to believe that, by paying for the initial cost of the line, service could be secured indefinitely at the same rate for which it was furnished in the adjoining city or for about the same rate, the minimum monthly charge probably being greater. The company now finds it cannot afford to rebuild the extension under the rates charged. The customer, if required to assist in the rebuilding, becomes dissatisfied. This condition is one of the causes of the present study of trying to prepare a satisfactory extension rule.

Another condition to be taken into account when writing an extension rule is what is the most convenient method for the customer to pay his bill. Ninety-nine per cent of all public utility service has been rendered to and paid for by customers whose income is received monthly and whose bills are paid likewise. That was the most convenient and accepted method. Charges made monthly covering excess extensions to utility distribution systems to serve such customers would fit in the general method of making payments. But if in building an extension to serve a rural customer or farmer provision for making payments other than monthly is allowed it may make the securing of this class of customer easier and afford greater convenience to the farmer in arranging his payments, particularly that required for the extension. The farmer's income is neither regular by the month or year. Crop seasons prevent regular monthly incomes and crop failures prevent regular annual incomes. Generally the farmer desires to spend freely following good crop and income years and to be able to curtail expenditures during lean years. The merchant and banker serving rural customers realize this well.

Furthermore, the extension rule should, if possible, be so constructed that the existing rates will apply to the new customers and at the same time not cause the new capital to disturb the present rate base. The extension should also be made so that, if in the future the property of the utility is appraised and a new rate base is established, the charges to cover extensions will reflect the changed rate base.

A GENERAL EXTENSION RULE

With all the above conditions in mind the method of extending distribution systems as set out below is offered as a general extension rule. The amounts, constants, units, etc., used in the rule at any place are to be derived from the particular distribution system to which the rule applies, and these can easily be obtained from the books of the system. Illustrations in the application of the proposed extension rule are given near the conclusion. The units shown in the figures and used in presenting the rule are arbitrary and are considered as those appearing in making an electric line extension, but following the explanation of the rule there will be shown how it will apply to three existing distribution systems, a water, a gas and an electric system. Assuming the investment in distribution system is $25.00 per customer and that this will build 100 feet of two wire pole line the extension rule may read:

> The company will make extensions to its present lines a distance of 100 feet to serve any customer, the cost of such extension being estimated to average $20.00 and is called the "Free Limit extension." For customers requiring extensions greater than the Free Limit such extensions will be made by the company and for every 100 feet or major fraction thereof above the Free Limit extension the customer will have added to the monthly bill estimated on the standard urban rate applying to the class of service to be furnished an extension charge of 20 cents.
>
> If the extension is made to serve more than one customer the extension charge will be prorated between the customers served on the basis of the number of 100 feet sections of the extension or major fractions thereof between each customer and the point where the extension is to be attached to the company's present lines after deducting a Free Limit extension from each customer. As customers are added or taken off the extension, the extension charge will be adjusted accordingly and prorated on the basis above described. As customers are added at an average of one for every 100 feet of the extension the point at which the extension is considered to be attached to the company's present lines will be moved forward accordingly.

EXAMPLES OF APPLICATION OF EXTENSION RULE

The following concrete examples together with the sketches attached and numbered likewise illustrate how the extension charge is to be applied. The present distribution line in all the figures is indicated by the dotted line . . . . and the extension by the solid line thus —·—.

Assume an extension of 500 feet to serve the first customer called A (see fig. 1). There are five 100 foot units of length, which unit of length has been taken as the average length of line per customer the company now has in its distribution system to serve its present customers, and the average cost is $20.00 per unit. The company agrees to bear the cost of one customer unit length for the new customer. This is called the Free Limit and is marked Fl-A, Free Limit for customer A. To avoid disturbing the present rate base and to enable the company to furnish service to A at the standard rate, customer A should be charged an amount sufficient to pay interest and depreciation on the extra amount of money invested for him over that of the regular extension customer. For ease of keeping record and understanding the extra charge should be shown as so much for each unit of extension and the total billed as an extension charge added to the regular rate charge. The extension charge of 80 cents in this case is made up of four unit charges of 20 cents each (see fig. 2).

Assume a second customer B is added as in figure 2, the Free Limit or first 100 feet of the original extension becomes chargeable to B

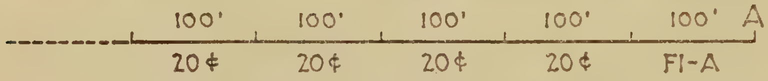

Fig. 1. Extension Charge, A—80 cents

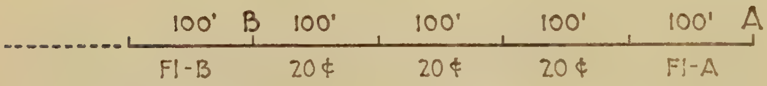

Fig. 2. Extension Charge, A—60 cents, B—00 cent

and the first customer's monthly extension charge will be reduced by one unit charge or to 60 cents.

If the second customer B is added in the second unit or 100 foot section of the extension made to serve the first customer the first customer's extension charge will be reduced to 50 cents and an extension charge of 10 cents added to the second customer's bill. This is shown in figure 3.

If the second customer is added in the third unit or 100 feet of the extension made to serve the first customer, the first customer's extension charge will be 40 cents and an extension charge of 20 cents added to the second customer's bill, as shown in figure 4.

If a second customer is added to the second unit or 100 foot section and a third customer, C, added to the fourth unit or 100 foot of the extension made to serve the first customer, as in figure 5, the first customer's extension charge will be $16\frac{2}{3}$ cents per month, the second customer's extension charge will be $6\frac{2}{3}$ cents per month, and the third customer's extension charge will be $16\frac{2}{3}$ cents per month.

If another extension unit of 100 feet must be made beyond the original extension to serve the third customer, C, the extension charges for each will be A, $26\frac{2}{3}$; B, $6\frac{2}{3}$; C, $26\frac{2}{3}$ cents; as shown in figure 6.

In figure 7 below a lateral extension is made two units or 200 feet in length to serve customer C.

The two additional units are chargeable to C only and the other units of the original extension prorated between those it is to serve.

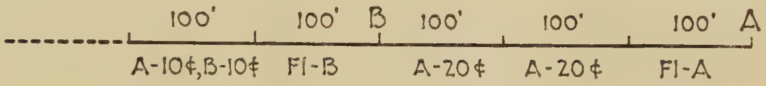

Fig. 3. Extension Charge, A—50 cents, B—10 cents

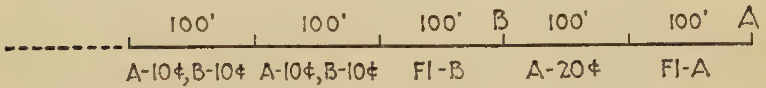

Fig. 4. Extension Charge, A—40 cents, B—20 cents

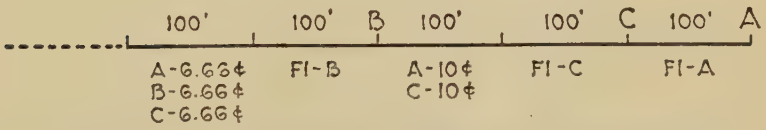

Fig. 5. Extension Charge, A—16.66 cents, B—6.66 cents, C—16.66 cents

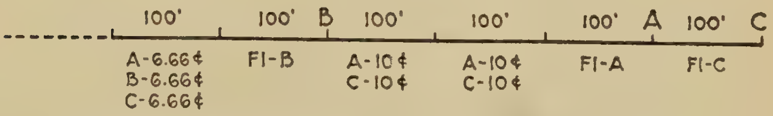

Fig. 6. Extension Charge, A—26.66 cents, B—6.66 cents, C—26.66 cents

The unit is divided equally between those customers it serves, allowance of a Free Limit unit having been made for each customer.

Figure 8 shows how the extension charges are made with A and C attached at the same point. The results are the same as found in example 5 above.

If five customers were attached to the extension at the point A is attached, the Free Limit allowance would eliminate all extension charges.

In a similar manner an extension of any length may be made for any number of customers and by use of the extension charge the burden of the extension is properly divided between all customers served. As new customers are added the extension charge is easily readjusted. When there is an equivalent of one customer per unit of length for a part of the extension lying between some point on the extension and the point of connection of the extension to the main system the extension charge is cancelled for that part on which that average obtains.

If an extension requires three wires to serve a power customer a slightly higher and proper charge per unit of length may be made against such customers. Various classifications of customers may be made and the investment cost per unit length of line per customer determined.

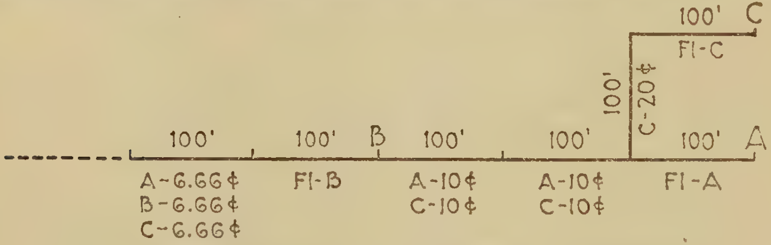

FIG. 7. EXTENSION CHARGE, A—26.66 CENTS, B—6.66 CENTS, C—46.66 CENTS

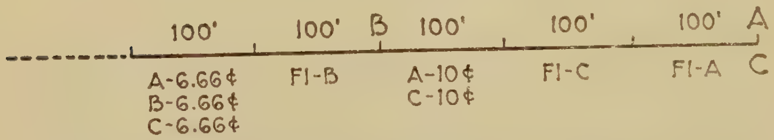

FIG. 8. EXTENSION CHARGE, A—16.66 CENTS, B—6.66 CENTS, C—16.66 CENTS

This rule may be applied to serve rural customers as well as urban. The utility may not consider it wise to built a line to a farmer customer without asking the farmer to deposit a sum of money to pay for the cost of the line. If the farmer does pay for the line the question of ownership is brought up. The utility is the logical party to maintain and operate it. Should the utility be allowed to capitalize and earn on the line is a question often discussed. There are many conflicting conditions to consider. Under the proposed rule it is suggested that the utility finance the extension. It can secure money more cheaply than the farmer and can immediately capitalize the investment. To safeguard the utility against a loss on the extension the farmer should be required to deposit with the utility a sum equal to the present worth of five or ten years payments of the extension charge, the value of the money being taken at about its cost from bonds. There is no doubt that the utility will deliver the service so the farmer's money is safely spent by him. Furthermore the farmer will make the deposit at a time when he feels able and then can enjoy the service at a reasonable monthly charge the five or ten years thereafter. If no new customers are added during the five- or ten-year period following the building of the extension the farmer can then at the expiration of that time be billed monthly for the extension charge and the utility has not assumed a risk. If the farmer happens to have a good crop he can go to the utility at any time and pay the present worth of the extension charge for any number of years he may desire. It is made to fit the farmer's method of paying his accounts, especially the larger accounts.

For short extensions, as urban or suburban, the customers will probably elect to pay the extension charge monthly as it comes due, their income being on that basis. Also the period of time to be covered by an initial deposit may be made three to five years, instead of ten. The utility assumes less risk in making urban extensions than it does in making rural because of the continuous growth of the city, which guarantees additional customers within a comparatively short time.

If additions are made to the extension or new customers are added to the original extension adjustments can be easily made to those customers who have paid the extension charge in advance.

How the rule applies to an electric, water and gas distribution system is shown below. The figures were taken from the records in investigations made for rate making purposes. Such items as Engineering and Superintendence, Injuries and Damages during Construction, Interest during Construction and Legal Expense during Construction were prorated between Distribution Mains and Services and all other Fixed Capital on the basis of money invested. The investment in Distribution Mains and Services so found were:

Water	$66.09
Gas	$72.31
Electric	$27.20

The length of the lines of the distribution systems per consumer was:

	feet
Water	53.51
Gas	50.63
Electric	91.25

Applying the rule, the extension charge per month for each unit of length above the free limit length, allowing for interest and depreciation, 9 per cent on the water and gas lines, and 12 per cent on the electric, is:

	cents
Water	49
Gas	54
Electric	27

If an extension of 500 feet is to be made of the various distribution systems, the number of unit lengths will be:

Water	9
Gas	10
Electric	5

If the extension is made to serve one customer, one free limit unit will be allowed and the customer in each case will be billed for the following number of units.

Water	8
Gas	9
Electric	4

The monthly extension charges will be:

Water	$3.92
Gas	4.86
Electric	1.08

If conditions are such that the utility furnishing the service is justified in requiring the customer to make a deposit sufficient to pay extension charge for five years, the deposit should be:

Water	$202.72
Gas	251.28
Electric	55.84

If the customer should be allowed to pay the extension charges monthly, the total amount that would be paid in five years would be:

Water	$235.20
Gas	291.60
Electric	64.80

The utility should have in most cases the power to determine the period of time the deposit should cover when application is signed for an extension and service.

If the customer were required to pay the entire cost of the extension, less one free limit unit, on the basis of the average cost of mains as used above, the deposits required would be:

Water	$528.72
Gas	650.79
Electric	108.80

If the electric company above is requested to make a two wire extension $\frac{1}{3}$ mile in length to serve a rural customer, assuming the present unit length per customer is 91.25 feet, there will be 19 units of extension. One is to be built free by the utility leaving 18 units to be covered by an extension charge. Allowing 12 per cent for interest and depreciation the monthly extension charge per month is 27 cents or a total monthly extension charge of $4.86. If the customer is required to deposit the extension for 10 years in advance the total amount will be $437.59. The total amount that would be paid in monthly payments would be $583.20 in ten years. This charge is based upon the city distribution system used above, where no deduction was made for street lighting service. By making proper deductions, as for street lighting and longer pole spacings, the extension charge will be less than is indicated above for rural extensions, possibly 30 or 40 per cent. The amount can be easily determined with sufficient accuracy to justly apply the rule.

If three phase service is required the extension charge can be increased proportionately to take care of it. The extension rule does not cover special equipment for substations as may be required by the customer, variation being required here as it is required in the urban territory.

The extension rule as given above provides that:

The company can definitely determine the basis for making extensions.

The customer can be definitely informed of how his charges are to be made for the service.

The extension charge can be paid in a manner suitable to all parties concerned, that is, if a part of the customers served by one extension desire to pay the extension charge monthly and others for a longer period, even though both classes of customers are served by the same extension, proper charges are made.

The extension charges operate jointly with the rates charged for service in producing the proper revenue and changes in the rate base are reflected in the extension charge.

The extension charge be based upon the property to which it applies.

The extension charge be automatically reduced as new customers are added and the resulting extension charge be equitably adjusted between the customers served.

CONTINUOUS VERSUS PERIODIC READING OF METERS AND BILLING[1]

H. P. Bohmann:[2] Meter reading is the foundation of the revenue of a water works and in order that the amount of water consumed may be intelligently computed it is essential that this work be accurately, honestly and frequently performed. At Milwaukee with 78,200 meters in service January 1, 1926, meters of small consumers are read monthly, meters of large consumers bi-weekly and contractors' meters weekly.

While the duties of a meter reader are primarily the recording of the registration of the meters, he has other functions or duties that are scarcely less important to the Department.

TESTING FOR ACCURATE REGISTRATION

These include testing of the meter to ascertain if it is properly registering. Only by frequent readings can the department have a check on the performance of the meters and by a proper method of reporting all meter defects and the immediate remedying of those defects by an efficient repair department can the department be in a position to render bills that are just and equitable.

Where many meters are in service thousands of accounts must be "averaged" each year on account of meters being temporarily out of order. The period during which a meter is not operating properly is greatly reduced by frequent readings of the meter, with a result that with monthly readings the average length of time a meter would be out of order before being discovered would be but 15 days. Bills when rendered therefore reflect to a greater extent the actual consumption than if a meter is out of order the greater part or all of the period covered by the bill.

Frequently when consumers receive "averaged bills" complaint is made in regard to the quantity of water consumed. When the consumer can be shown that only a small fractional part of the period is "averaged" and the balance actual registration with the short averaged portion on the basis of the actual registration, it is usually an easy matter to convince him as to the equity of the charge. This applies especially to large consumers where the amount involved is considerable.

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[1] Topical Discussion before the Buffalo Convention, June 7, 1926.

[2] Superintendent of Water Works, Milwaukee, Wis.

All meters of large consumers in Milwaukee are read bi-weekly thereby still further reducing the average length of time the meter is out of order and lessening the time covered by the average when computing bills. Meters set for construction purposes are read weekly, which gives us an excellent check on the consumption on account of the great variations during different periods as the construction progresses. It prevents in a great measure tampering with the meter, either intentionally or otherwise.

Frequently when extensive leakage exists and the meter is recording at or near capacity for some time, some part of the meter gives out and the meter stops registering. This is especially true when meters have been in service for a long time. At a normal rate of consumption a meter might function properly for a long time. When an unusual strain is put on it, however, some part usually gives out. Unless a meter is read frequently no knowledge of such unusual conditions is discovered and a great deal of revenue may be lost to the department.

DETECTION OF UNUSUAL CONSUMPTION

Secondly, investigation of the cause of unusual consumption and notification of the consumer are assured.

While the water meter furnishes the most accurate basis for charging for water, it serves another important purpose, namely, that of a safeguard and protecton to the consumer as well as to the water works in case of leakage, etc. It measures accurately the consumption and all extraordinary conditions existing are early reflected by the registration of the meter. Again frequency of readings has the advantage of bringing discovery with the least delay and affording an opportunity to the consumer to avoid excessive water bills.

At Milwaukee, whenever an unusually large registration is shown by meter, a notice is left with the owner, if he resides on the premises or mailed to him if he does not, calling his attention to the extraordinary condition and asking him to investigate without delay to avoid a large bill. On account of reading meters monthly and large meters bi-weekly a great saving is shown, as the average length such condition exists will not exceed 15 days for small consumers and 7 days for large consumers. This is especially valuable where underground leaks exist that find their way into a drain or sewer and do not show on the surface.

For example, take a small consumer in moderate or poor circumstances whose water bill amounts to only a few dollars annually. Suppose an underground leak existed that did not make itself apparent on the surface or in any other way. If the meter is read frequently the very next time the reader called after such a condition developed he could not help discovering it. By notifying the owner at once, steps could be taken immediately to have the necessary repairs made with but small loss. On the other hand, if this condition had been allowed to exist for three or more months before discovery, a tremendous bill would have accrued, with a hardship on the consumer with benefit to no one. While it would temporarily increase the revenue of the department, it would leave a bitter feeling in the mind of the consumer toward the department. Even a very small leak running 24 hours a day will in three months time amount to considerable.

At Milwaukee approximately 26,000 "large consumption" notices were delivered to consumers or owners during the year 1925, which has resulted in a great saving to consumers.

We have on file many letters of thanks from consumers for calling their attention to high water consumption. Consumers realize that the efforts of the department are to furnish the best possible service and to help them avoid unnecessarily high water bills.

Most complaints received are in regard to large consumption. With our frequent or continuous readings and close attention to conditions by meter readers, we are able to adjust satisfactorily all complaints and avoid controversies with consumers.

DETECTION OF VIOLATIONS OF RULES

Thirdly, policing of districts in regard to violation of the rules and regulations of the department is possible through frequent meter readings.

Meter readers are obliged to familiarize themselves thoroughly with every condition in their respective districts. While primarily engaged in reading meters and safeguarding the interests of the consumer, the meter reader also safeguards the interests of the department as well as that of the city in general. He must see that contractors have proper permits when using unmetered water, report all illegal opening of fire hydrants, leaks or breaks in mains, etc., or any other violation of the rules and regulations of the department. They co-operate also with other divisions and departments of the city service in regard to sanitary and health conditions in their district.

Water meters frequently run over, i.e. reach their full dial capacity and repeat one or more times each quarter. Where meters are read only periodically, it is practically impossible to compute accurately the amount of water consumed, as it is not evidenced by the meter that such had been the case and considerable revenue may be lost to the water works in this manner.

By reading meters continuously the department is in a position to employ meter readers permanently, insuring accuracy and efficiency in the performance of their duties.

Frequent readings of meters protect the water works, insofar that they eliminate almost entirely the tampering with water supply or meters. Taking readings infrequently or at long intervals affords an opportunity for all kinds of liberties with the water supply or meters by unscrupulous consumers and many times unintentionally by honest consumers, with a result that the department may lose many times the cost of additional inspection. If water supply or meters are tampered with, it leads to almost immediate discovery before the consequences are considerable.

It is generally conceded that where meters are not read frequently, when leakage occurs some abatement or adjustment of the amount of bill should be made and usually on a 50 per cent basis. It is claimed that approximately 3 per cent of the total assessment for water rates is so rebated where that practice is followed. Assuming this figure on an annual assessment such as the city of Milwaukee, the amount of loss to the water works due to such adjustments would approximately amount to the entire annual expense for reading meters on a monthly basis. As a matter of fact the abatements made by the city of Milwaukee due to leakages do not average $50.00 annually.

A water works, especially if municipally operated, should not endeavor to make money, but rather to give the maximum of service at the lowest rate to the greatest numbers of consumers.

That Milwaukee is not the only city that believes in continuous meter reading is evidenced by an extract from THE JOURNAL, Vol.

1, No. 2, June 1914. The report of the Committee on Tabulation of Water Rates, etc. shows that, of a total of 257 cities, 177 or 69 per cent read meters monthly, while only 69 or 27 per cent read meters quarterly.

GENERAL PRACTICE IN FREQUENCY OF METER READING

The above report being too ancient to reflect present day practice, questionnaires were sent to 37 cities having a population of 100,000 and over. Thirty-two replies were received, representing a total population of 11,617,000 with 1,701,200 meters in service, an average of 86 per cent of water consumers metered. Abstracts from the above revealed the following:

Frequency of meter readings

Small consumers:	
Semi-annually	1
Four-monthly	2
Quarterly	16
Bi-monthly	3
Monthly	10
Total	32

10 or 31 per cent favor monthly reading
3 or 9 per cent favor bi-monthly reading
16 or 50 per cent favor quarterly reading
3 or 9 per cent favor less frequent reading

Large consumers:	
Quarterly	7
Monthly	23
Bi-weekly	2
Total	32

7 or 22 per cent favor quarterly reading
23 or 72 per cent favor monthly reading
2 or 6 per cent favor more frequent reading

Do you favor monthly readings?

15 or 47 per cent favor monthly readings
13 or 41 per cent favor monthly readings large consumers only
4 or 12 per cent favor less frequent readings

All replies received show that consumers are notified in case of leaks, large consumptions, etc. This is consistent practice as far as large consumers are concerned, for 25 or 80 per cent read large meters monthly or oftener. How this works out with the smaller consumer is hard to determine, as only 10 or 31 per cent read small meters monthly.

It would, appear therefore, that the small consumer, to whom perhaps the large bill is a greater hardship than to the large consumer, is not getting the same protection through the notification of large consumptions, leaks, etc., notwithstanding the fact that the small consumers represent a great majority of water takers. It is a well-known fact that, where leakage exists, it becomes greater the longer it exists.

On the other hand, where meters stop registering or become out of order, or read but periodically or infrequently, difficulty is encountered in regard to computing properly the consumption due to seasonal or other conditions. Again the small consumer is not getting the proper protection and unfair and unjust assessments to the department as well as to the consumer may result.

Abstracts from the replies received prove conclusively that it is to the best interests of all concerned to read the large meters, or the small minority, frequently. Why should it not then also be to the best interests of all to read the small meters or the great majority just as frequently?

Eighty-eight per cent of the cities reporting are in favor of reading large meters monthly, while 47 per cent also favor monthly readings for small meters, with only 12 per cent in favor of less frequent readings.

If meters are read only as frequently as bills are rendered, it does not tend to the best service. Usually readings are taken during the final month before the billing period as rapidly as possible in order to get out the bills. Therefore, readings taken during the interim period afford readers better opportunity for observing conditions, testing meters, etc. It should be the ambition of a meter reader to get his route in such shape during the interim so that when taking the final readings for billing he will have as little trouble as possible. Where bills are rendered infrequently, I believe it to be false economy to use that as a guide or proper period for reading meters. No direct relation exists between the reading of the meter and the rendering of the bill.

The following is a résumé of the advantages of continuous over periodic readings of water meters.

1. Meter defects discovered shortly after occurrence.
2. Reducing period "averaged" when computing accounts, so that bills when rendered reflect as nearly as possible actual consumption.
3. Large consumptions, leaks, etc., discovered shortly after occurrence, affording consumer an opportunity to have repairs made and avoid excessive bills.
4. Minimizes difficulty in adjusting complaints about excessive bills.
5. Prevents violations of rules and regulations, illegal use of water by contractors, etc., coöperation with other departments.
6. Permanent employment for field force, thereby increasing efficiency.
7. Prevents tampering with water supply or meters.
8. Makes abatement or adjustment of large bills due to leaks unnecessary.

CONTINUOUS VERSUS PERIODIC RENDERING OF BILLS

Since the establishment of the Milwaukee Water Works metered water rates at this city have been collected quarterly. On January 1, 1926, 78,200 bills were issued and, with the additional accounts to be added during the year, approximately 320,000 bills will be issued and collected during the current year.

There has been no demand from a single individual for a change from the present system which has stood the test for fifty odd years under many administrations. It must have, therefore, some real merit.

Various plans have been investigated from time to time without finding a better one and all of them are more costly.

An abstract from the replies from 32 cities, as to the frequency of rendering bills, is shown below:

Frequency of rendering bills

Small consumers:	
Annually	2
Semi-annually	5
Quarterly	18
Bi-monthly	1
Monthly	6
Total	32

6 or 19 per cent favor monthly billing
1 or 3 per cent favor bi-monthly billing
18 or 56 per cent favor quarterly billing
7 or 22 per cent favor less frequent billing

Large consumers:

Semi-annually	2
Quarterly	11
Monthly	19
Total	32

19 or 60 per cent favor monthly billing
11 or 34 per cent favor quarterly billing
2 or 6 per cent favor less frequent billing

In 56 per cent of the cities reporting quarterly billing is favored for small consumers, while 60 per cent favor monthly billing for large consumers. Seventy-nine per cent of the cities favor monthly billing for both small and large consumers, while 90 per cent favor quarterly billing.

Opinions differ greatly as to how often bills should be rendered, varying all the way from monthly to annually, but differ only slightly from the actual practice as reported below.

Small consumers:

Annually	2
Semi-annually	4
Quarterly	16
Bi-monthly	1
Monthly	9
Total	32

9 or 28 per cent favor monthly billing
16 or 50 per cent favor quarterly billing

Large consumers:

Semi-annually	3
Quarterly	12
Monthly	17
Total	32

17 or 53 per cent favor monthly billing
12 or 38 per cent favor quarterly billing

I believe that both small and large consumers should be billed at the same time, as that makes for the greatest economy.

Railroads, tanneries and other large manufacturing establishments have a large number of meters in various parts of the city, some rated as small and others as large consumers. If small consumers are billed less frequently than large consumers, they would receive some of their bills monthly and others quarterly, causing considerable confusion in their accounting department.

The period between billings should be of such duration as to meet every local condition of the community to which it applies.

If large consumers are billed more frequently than small ones, there is additional expense.

A certain amount of confusion is likely to arise due to accounts passing either side of the dividing line between those that are billed frequently and those less so. An account may be in one class for a certain time and again in another at other times, due to increases or decreases in consumption.

In cities where water rates are not assessed against the property and the right of lien does not apply, but rates are assessed against occupants, a goodly per cent of whom are tenants and frequently change, frequent collection may be desirable.

Cities having a minimum or a service charge sufficiently large may be justified in more frequent collection on account of the revenue involved.

Frequent collection is not so vital as frequent reading and perhaps the amounts of bills would be the best obtainable guide as to the procedure to be followed in that matter.

Water bills at Milwaukee, unlike telephone, electric light and gas bills are of much smaller amounts; in fact, so small that it would not justify monthly billing and collection. A table prepared as of January 1, 1926, shows that at our present rate, out of 78,200 accounts, 71,500 or 91 per cent would average less than $1.00 per month. Of these 1250 would pay less than 23 cents per month, 6030 between 23 and 30 cents per month, 15,830 between 30 and 42 cents per month and 14,680 between 42 and 56 cents per month; amounts too ridiculously small to warrant the expense of monthly collection.

It is evident that the more frequent the billing the greater the expense must necessarily be for billing and collection.

J. E. Gibson:[3] I can fully endorse the statements presented by Mr. Bohmann as to the many advantages of the continuous reading and billing of meters as opposed to the periodic readings. It certainly reduces the congestion in the office, keeps the office force occupied under a systematic routine, and eliminates materially the possibility of errors, due to the fact that the work goes along in a systematic and orderly manner without those periodic rushes of speed and long hours.

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[3] Manager and Engineer, Water Department, Charleston, S. C.

When the City of Charleston purchased the private water company, I found that we had a chaotic condition. The industrial or commercial meters were read monthly and billed accordingly; a percentage of the domestic meters were read quarterly and billed immediately after reading; the flat rates were billed quarterly; then at the end of the year, the domestic consumers were given an adjustment provided they had not used the minimum for the twelve months of $12.00, but had overpaid during some quarter, contract being made for a yearly rather than for a quarterly period.

The first resolution adopted by the Commission was one authorizing us to meter everyone and to do away with all flat rate consumers. We proceeded to district the city into nine major districts with a 10th district which is known as the "monthly" or "commercial" district, where meters, on account of their large consumption, are read monthly. These districts were then sub-divided into routes and the routes were limited not to exceed 150 meters to a route. The order of reading is to commence at the first district during the first month of the year, reading district No. 1 in the first ten days of the month; district No. 2 in the next ten days; and district No. 3 in the next ten days. Then proceed to the 4th, 5th, and 6th districts in the second month of the quarter, and the 7th, 8th, and 9th districts in the third month of the quarter, repeating the above order at the beginning of the fourth month. As we have laid it out, this means that we read and bill about 200 meters each day; then toward the end of the month, we have the monthly district to read, which increases the work for only the first few days of the succeeding month.

Bills are due and payable within ten days of rendition, so it will be seen that ordinarily we read about 200 meters each day. The following day these bills are made out and mailed, and within the next ten days probably 90 per cent are paid.

The total number of bills paid in dollars is summarized each day, which added to the previous amount billed and collected, gives the total amount of water in cubic feet and dollars billed up to and including that day, with the total amount of rates, so that in effect we carry a perpetual balance. At the close of each business day we know the exact amount of money owing the department for water billed. We found this, as before stated, to equalize the work in the office, reduce the number of errors, and give the Department ample working funds to discount bills and meet its obligations promptly.

A record is kept of the errors made in reading, billing, and collecting. At first the keeping of this record was objected to by some of the employees, but after they found that the purpose of it was not to use it as a lever to jack them up or scold them for dereliction of duty, but rather to foster a spirit of reducing errors, it met with the approbation of all, with the result that we have greatly reduced errors in all departments. I think during the year 1925 the total number of errors due to meter readings (approximately 50,000 readings) was only 15. Of course, there may have been more, but, if so, we did not catch them. I think you will agree with us that this is an enviable record, and while we hope to reduce errors in the future, it will be pretty hard to do so.

W. Z. Smith:[4] I had a question in my mind that I wanted to ask Mr. Bohmann. I was struck with the remark in reading his paper to the effect that he had so many bills that were less than a dollar per month. May I ask Mr. Bohmann if you have a minimum monthly charge or a quarterly charge for water in Milwaukee?

H. P. Bohmann:[2] We have not, but we have a service charge of $2.00 a year. The average householder does not pay to exceed $8.00 a year, which includes the service charge, regardless of the size of the meter or service pipe. We have a uniform rate for everybody, whether he uses a thousand gallons or a million gallons. The small consumer gets his water at the same rate as the large consumer. We have one consumer who pays eighty thousand dollars a year. You pay 50 cents a quarter, whether any water is consumed or not, but when you do consume water, you pay at the rate of 7 cents per 100 cubic feet. We took twenty family homes in each section of the city and they averaged only $6.00, which included the service charge. We counted 120 homes.

W. S. Patton:[5] I agree with Mr. Bohmann that it is a good plan to read the meters monthly, but it requires considerable extra labor to bill monthly. In Ashland, we read our meters monthly, but we bill quarterly and I think we save a lot of trouble and considerable expense. After the meters are read between the quarterly collections, we send a notice to those who show an unusually large consumption of water. It runs something like this; "since a certain date, so many thousand gallons of water have passed through your meter. It would appear that there is some leakage in your plumbing. The water works is not responsible for the size of your water bill, but is pleased to coöperate with you in keeping it at the minimum." This has made many friends for us at Ashland. The only improvement I can see is that, if we were to divide our consumers into, say, three sections and bill one-third each month, I believe we would have the ideal arrangement. A great many of our consumers use only about a dollar or a dollar and a half's worth of water a month. It seems hardly worth while to mail them a bill for such a small amount. A quarterly bill is no hardship on the consumer and saves us extra expense.

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[4] General Manager, Water Works, Atlanta, Ga.

[5] Manager, Water Works, Ashland, Ky.

W. Z. Smith:[4] In Atlanta, we have a minimum monthly charge for consumers, the smallest bill rendered being for $1 per month. The minimum is larger for larger consumers. It is based on the size of the water connection. We have about 45,000 accounts. In keeping these accounts, we employ what is known as the daily billing system. The city is zoned into twenty-five zones. They are indicated by letters, using each letter of the alphabet with the exception of the letter I. We read the meters in one zone each day, starting with zone A and continuing through the alphabet, winding up with zone Z. We render the bills on a zone each day. Of course, the zones do not each pay up fully on the day due, and they overlap. As the coupons are brought in, they are distributed in the zones, so that when the discount period has expired we have all of the payments of that zone properly distributed. By noon of the following day we have all of the delinquencies recorded, so that they can be immediately notified. The whole process results in our completely clearing about 1700 accounts a day through our office. We do not keep consumers' ledgers. We use the coupon system entirely in handling our bills. It is all carried into a control account, so that we know at the close of business each day the charges on our books and the balances of unpaid bills.

We are strongly in favor of billing the consumers monthly for their water bills. We take the position that, if it is well for a gas or an electric or a telephone company to collect their bills monthly, it is just as good business for a water company to collect bills monthly. We take the position that a water company is rendering a public service and that the consumer is entitled to know each month how much his water bill is. If he has a large bill, the result of leakage or waste, he is entitled to a notice of this fact. In carrying out that idea, each meter reader is supplied with a book of blank notices. When he reads a large bill, knowing that he is required to leave a notice with the consumer of this large bill, he is more careful to know that he is correct, for he realizes that there is likely to be a request for an examination of the service and he would not like to be caught in error. He leaves a notice with the consumer, and if the service is not one that it would take too long a period of time to inspect, the reader goes in and examines such fixtures as are available, bathroom, toilet and washstand, sink, etc., to see if there is any visible leak. He calls direct attention to this leakage, thereby giving to the consumer every advantage possibly in rectifying the trouble and stopping excessive bills. Since we ourselves have adopted the system of daily billing, the power company in Atlanta have likewise adopted the system and the same is true of the gas and electric bills.

H. P. Bohmann:[2] We have similar machinery. The skeleton bills are prepared by the addressograph and then filled out on the billing machine. With our flat rate there is practically no checking necessary, because the machine accumulates the cubic feet and the total amount. If you get out a thousand bills, you multiply the quantity by the rate. If it balances, no checking is necessary. It seems to me your system has some disadvantages where you have a ledger card and the clerk who has charge of that account can see if there is a falling off of that registration. Apparently, you do not assemble those different readings, do you?

W. Z. Smith:[4] We carry that on the route book itself. We have on the account of any water consumer by the month, the monthly consumption in one column on the route book of his water for the last year, as a guide to the meter reader, and to the clerical force in charge of this account. Each month, when the meter is read, the quantity of consumption is carried into the next column, so that they have it before them all the time in the meter reader's book.

H. P. Bohmann:[2] Who watches out to see whether the account is falling off?

W. Z. Smith:[4] The control clerk in the office bills from the report of the meter reader. If the account is falling off, he brings it over to the chief of his division, who has an investigation made until he is satisfied there is no loss.

H. P. Bohmann:[2] I do not agree with you as to the monthly billing. In Milwaukee the telephone bill is $3.75 for the average dwelling, and the water bill is not 75 cents. That would hardly justify getting out 78,000 bills every month.

W. Z. Smith:[4] Our rate is different from the rate of Milwaukee. Therefore, we feel justified in billing monthly. We have about 20,000 accounts that run above the minimum rate and the monthly bills of many of our domestic consumers bills run from $5 to $60 a month.

H. P. Bohmann:[2] On a meter basis?

W. Z. Smith:[4] Yes. We have a few consumers whose bills run nearer a hundred dollars a month on the meter basis for their domestic water.

A Member: Do they run a brewery or something of that sort?

W. Z. Smith:[4] Swimming pools, etc.

Muscol Burnett:[6] I should like to ask Mr. Bohmann about his rates. Is there not at present a frontage or property charge in Milwaukee that goes with the water?

H. P. Bohmann:[2] Do you mean for the water pipes?

Muscol Burnett:[6] Yes.

H. P. Bohmann:[2] Yes, there is a property charge on a frontage basis for laying a six inch water main. During the last sixty years

[6] President, Water Company, Paducah, Ky.

the property owners have contributed about two million dollars out of the eight million dollars spent for this system.

Muscol Burnett:[6] They are not paying quite as much as in Atlanta, but still they are paying more than the minimum rate.

H. P. Bohmann:[2] The average householder pays about $6 a year.

Muscol Burnett:[6] And he pays for the water pipe?

H. P. Bohmann:[2] A few years ago the investment was 60 cents a front foot; figure the interest on that, and it would be very small. On the other hand, the water department transferred last year 300,000 dollars to the city treasury.

D. C. Grobbel:[7] We changed our system or method of accounting and meter reading, in the past three months. We finished it on the 15th of March, making the change in all the bookkeeping equipment. Some wanted to put in the Baltimore system with stub accounting. I believe stub accounting is all right for a private water company, but not for a municipal department that has a lien upon the premises for the water. It seems to me that a historic record is necessary at all times when you want to place a lien upon real estate. The equipment agents could not impress me that they had such a historic record in a bunch of stubs that was piled up in the garret or basement or were thrown away after the third year. For that reason we in Detroit adopted the historic record, in other words, a card system with ledger cards. We also equipped our establishment with about 40 or 50 thousand dollars' worth of new equipment, changed our methods of handling the accounts, changed our methods of reading meters, and from three districts we jumped to thirty-six districts. In other words, we have continuous readings and we do get away with 230,000 meter accounts every three months, or practically 75,000 accounts every month. We believe that we have a very good system. We read meters monthly, that is, meters 3 inches and over. We have many meters in Detroit that run 3 to 4 inches. These are read monthly for check reading, but I cannot see any convenience or any good in billing monthly, because labor is too expensive in Detroit to send a bill for 45 or 50 cents to probably 80 per cent of the consumers.

[7] Assistant Secretary, Board of Water Commissioners, Detroit, Mich.

A MEMBER: I would like to ask the gentleman from Milwaukee what time expires from that of reading of the meter until the bill is delivered?

H. P. BOHMANN:[2] On the first of June we begin reading. The bills are issued on the second. The meters read on the second are billed on the third, so that by the end of June all meters are read and the bills are made out and ready for delivery. Then the meter readers deliver the bills. It takes about five days to deliver the bills.

A. COLLINS:[8] We have used the district system since 1913, dividing the city into meters from an inch down and billing and reading them quarterly. Anything over an inch is read and billed monthly. We have a service charge according to the system of the meter, and the rate is added to that. We found an advantage in that and I think it is a good policy. It enables you to keep down your rate. The lower the rate, the less friction you have with the public. We have about 55,000 accounts, and 90 per cent of those are quarterly. We have been able to handle our cash-in with one cash window. We find it very important to keep a ledger account, for the conditions on property are changing. They are adding ice machines, which we find to be quite a cause of increase of water and other conditions are changing. In that way we have a continuous account and we find the first indication of danger. If the meter reader finds that the consumption is increased, he immediately investigates and leaves a written notice on the property. The consumer then comes into the office with an apology and a repair slip to certify that the repair is made. On the larger meters, we bill, as I say, monthly and put in a stop rate. We were influenced in that by the peculiar situation in St. Paul. We have an artesian basin there, and it is estimated that over 35 or 40 per cent of the water is taken from private well supplies. You cannot stop that legally, I guess. We found, for that reason, that having a service charge caused very little friction. We were afraid of it at first, but it was explained to the people that it enables us to keep down the rate and in the sprinkling season there was no waste on the property. Now we find a necessity for keeping those ledger records to show how recently we have changed the meter on that property and whether there is a condition there that requires correction.

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[8] Water Commissioner, Niagara Falls, Ontario, Can.

EXPERIENCES WITH STORAGE RESERVOIRS AT LOW LEVEL[1]

By William W. Brush[2]

New York has a diversified supply and we have had experiences with reservoirs at virtually every level, from full and overflowing in flood time to empty. Some of the experiences are interesting. They may be helpful to others who have had similar problems and perhaps have not solved them in just the way we have and others still who have not yet had those problems and will ultimately have them.

RESERVOIRS IN THE CROTON SYSTEM

In the Croton system there is the long, narrow, rather deep reservoir known as Croton Lake, about twelve miles in length with an available capacity of thirty thousand million gallons and about eight thousand million gallons unavailable.

Above that reservoir there are some ten reservoirs on the different branches of the Croton River, making the total available storage in that watershed one hundred and four thousand million gallons.

On Long Island there are virtually no reservoirs that amount to anything. Our big reservoir on Long Island holds, when full, just under 900,000,000 gallons, so we have virtually no problem that would develop from reservoirs that are empty.

Turbid waters

In the Croton, in the earliest years, there was the one reservoir formed by the old Croton Dam. It is about thirty-four feet from the top of the old Croton Dam to the level of the new Croton Dam and about three miles from the old dam to the new dam. Back of the old Croton Dam there was a storage capacity of two thousand million gallons and with this small storage a fairly substantial stream flow gave dirty water at the intake. This condition continued until there was sufficient storage in the Croton to permit of sedimentation taking place before the water was delivered.

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[1] Presented before the New York Section meeting, December 29, 1926.

[2] Chief Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

Even as late as 1910 and 1911 we had a good deal of trouble with Croton turbidity. When the present Croton Lake was utilized, the question came up of how to handle the Croton supply and until about 1911, this was accomplished by drawing down Croton Lake and making thereby available its storage to hold any heavy run-off which might occur. That method gave insufficient storage capacity and each spring a turbid supply was delivered. About 1911 that system was changed and a careful determination was made of just how much each one of the reservoirs above Croton Lake should be lowered so that the reservoirs would all fill simultaneously, assuming that the run-off was uniform per square mile. Croton Lake was kept full or nearly full under that system and thereafter, there was very little trouble with the turbid water from this source. Croton watershed has no extensive clay banks to furnish fine clay or colloidal clay that will remain in suspension for a long time in the water. With Croton Lake full and with the reservoirs above it drawn down so that the first flood flows can be used, we have found that the necessary sedimentation and clarification take place before the water reaches the main intake. The main intake at the new Croton gatehouse is just below the site of the old Croton Dam but the greater part of the water is taken at the Croton Dam and it is sent back about three miles through the old Croton aqueduct under the bottom of the lake to the new Croton gatehouse. That puts the aqueduct under an internal pressure, but the pressure is less than the external head of water and therefore there is no bursting pressure on the old Croton aqueduct between the new Croton Dam and the gatehouse three miles upstream. By taking in about three-quarters of the supply at Croton Dam, we are able to get the clearest water and the most satisfactory supply.

Troubles with vegetation

During the time that Croton Lake was being operated at a lower level, we had the exposed areas on which vegetation would spring up and, as these areas were exposed in the late spring or early summer, there would be a very substantial growth. The question came up whether we would or would not have trouble from this vegetation when the areas were again flooded, but no trouble developed. The vegetation looked heavy but when it dried in the fall it would not burn as the grass and other vegetation were not sufficiently closely matted so that the fire would spread. The upper reservoirs never had given us any trouble from this yearly growth of vegetation.

Under the plan of operation for the last eight years water has flowed each spring over the dam. Virtually everybody who is interested in water supply, and does not know much about the question of the available supply, thinks that because the water goes over the Croton Dam the system is not being operated profitably, and these persons wish to stop the water going over the Croton Dam.

If a water system is so operated that no water passes over the dam that system is being overdrafted for the greater part of the time. If New York City did not allow any water to go over the Croton Dam and did not allow any water to go over the Ashokan Dam—and none has gone over since 1917 when we first started to operate—it would mean that New York City would not have a supply available during periods of low run-off, because we would be utilizing the average yearly flow of the river which is about double the lowest yearly flow.

The wave action on the shore has never been troublesome in Croton from the viewpoint of turbidity. The sediment stirred up by wave action settles out very quickly after a high wind has subsided. The flood flows have been taken care of fairly well by the upper reservoirs and when the water comes over an upper reservoir dam it is usually a fairly clean water which flows down into the upper end of Croton Lake and then travels slowly down in the lake. By the time it reaches the dam it has become sufficiently clarified by sedimentation to be satisfactory.

My personal view is that there is no serious difference in the microscopic growth with reservoirs drawn down as compared with reservoirs held at higher level. When a reservoir is drawn down, if any particular growth that develops is troublesome, it is much easier and much less expensive to treat the water with copper and destroy the growth than if the reservoir is full.

Effect on bacterial content

The B. coli content is likely to be greater in the water reaching the supply if reservoirs are low at the time the heavy run-off occurs, but the B. coli are very satisfactorily destroyed by the chlorine treatment that New York has used. I believe very thoroughly in the double chlorination so that there is no question but what every particle of water which goes to the consumer has been subjected to at least one effective treatment by chlorine. Chlorine machines work very steadily, but in any plant there is a possibility of an interruption for a few hours in the course of a year's time, and water that once goes by the only chlorination plant is never treated by the chlorine. With double chlorination there is certainly no probability that any part of the water will get by both treatment plants without having been thoroughly sterilized by chlorination.

RESERVOIRS ON THE CATSKILL SYSTEM

In the Ashokan reservoir of the Catskill system there is the east basin with a capacity of about eighty or ninety billion, and the west basin with some forty billion. The tributary watershed of the Esopus creek, which is the main watershed that delivers into the Ashokan Reservoir, delivers directly into the west basin. The east basin has only a small local tributary watershed of relatively few square miles. The total contributory watershed for the entire reservoir, without considering the Schoharie, is 257 square miles.

By connecting up the Esopus watershed with the Schoharie watershed, there have been added 314 square miles of watershed. The Schoharie water flows through the eighteen mile Shandaken Tunnel which obtains its water from the reservoir formed by the Gilboa Dam which was completed last July. When full this reservoir holds twenty thousand million gallons. Up to this November, the water was delivered into the Shandaken Tunnel by a diverting dam that formed a small pond of a few million gallons capacity. Under the conditions that existed prior to the completion of the Gilboa Dam we could deliver about four hundred and fifty million gallons a day as a maximum through the tunnel. Now the delivery with the reservoir virtually full was, as I recall, about six hundred and thirty million gallons a day.

Up to 1924, we only had the Esopus available and we have operated with a view of utilizing all the water that came off the Esopus watershed. That operation has been successful and we have lost no water from the Catskill System, not even the leakage from the reservoir which was alleged, by one of the New York dailies.

The city has taken from the Ashokan reservoir for a period of several months approximately between six hundred and six hundred and fifty million gallons a day prior to the completion of the Gilboa Dam, whereas the approximate safe yield of the two watersheds without the Gilboa Dam was four hundred and fifty million gallons a day. That was a deliberate overdraft in the sense of drawing more than could be safely depended upon. We watched very carefully the contents of the reservoir in relation to the probable supply which could be obtained later in that year and subsequent years if we had a drought or low run-off period. We kept the draught so that by the operation of our pumping stations, by installing some emergency pumping plants further to utilize Croton water, and by the reduction in consumption that comes from house to house inspection and from appeals to the public, we would still be able to meet the needs of the city.

Unusual ranges in run-off

This year up to the end of October we had the lowest run-off of the twenty odd years that stream flow records are available in the Catskills; then, in November, we had the maximum run-off for the Esopus for that month since the records were first taken. We had on the average a thousand million a day come off the Esopus watershed during November. So this year has been a combination of very low run-off for the first ten months and very high run-off for the month of November, when we had a little over 7 inches of rain as an average.

With that system of operation, the Ashokan Reservoir level has varied very greatly. In 1923, just before the Shandaken Tunnel was finished, the reservoir was down below sixteen billion as against one one hundred and thirty billion as the maximum content. We intentionally drew it down on the basis of avoiding pumping because we expected that when the Shandaken Tunnel opened we would have, for the time being, a greater quantity of water than we would need with the pumping that we would normally maintain from the Croton and other sources.

The following June, 1924, we had the two basins practically full. There were one hundred and twenty billion in storage as against sixteen billion the preceding October.

With those basins drawn down we had the same experience as far as vegetation on the shores and the bottom was concerned, as we had in the Croton but there was no trouble from the vegetation. The waves would stir up some of the fine material previously deposited on the bottom as the reservoir was drawn down, but that material would quickly settle out and did not noticeably affect our supply.

In the spring, we were fairly fortunate in having enough clean water in the reservoir to allow us to hold the turbid water in the west basin and draw on the east basin until we had the turbidity reduced from forty to ten parts per million. When that water was mixed with the water in the Kensico the resultant turbidity was normally between five and ten in the spring, so that we only had a very few complaints and those were from people who were unusually sensitive to a slightly clouded water.

Effects of 1926 flood flow

After we had the Gilboa Dam completed, there came this flood of the middle of November. On November 15 and 16, there was a rainfall that averaged in the Esopus a little over four inches, in the Schoharie a little under four inches, but was quite varied. It was as high as eight inches, approximately, at certain points in the water sheds. We have ten gauging stations in the Esopus, and the Board of Water Supply maintains eight in the Schoharie, the Schoharie being still under the jurisdiction of the Board of Water Supply. Those gauging stations showed that the greater part of the fall was along the divide between the Esopus and the Schoharie. The water-came down with a high turbidity in both watersheds. I do not know what the maximum turbidity was; it was probably over a thousand. It became about one hundred and twenty as a maximum in the Gilboa Reservoir and also in the Ashokan Reservoir in the west basin.

That turbidity was caused by a very large percentage of finely divided clay and the clay banks are either more numerous or else more readily eroded along the divide where the greater part of the water fell than generally over the watershed, so that we had a greater percentage of fine clay in this turbidity than we had previously.

Today, six weeks after that storm, we still have about ninety turbidity in the west basin of the Ashokan Reservoir. The east basin was nearly empty at the time of the storm and we then continued to draw from the east basin until December 8 when the flow took place over the dividing weir, and from then on we had turbid water in both basins. In previous years we found that in about five weeks time the high turbidity had dropped to ten or below. Gilboa Reservoir was empty at the time of the flood and went up fifty-two feet the first day. At the end of a week the reservoir was within five feet of being full and where previously there had been a small pond there was a lake that was several miles long and perhaps half a mile wide, containing eighteen thousand million gallons. The maximum flow from each watershed for twenty-four hours was very nearly the same figure, a little over eleven billion, and the highest rate of flow from the Esopus showed about twenty-five thousand million or twenty-five billion at the height of the flood. Those were, as you can see, very sizeable quantities of water.

Treatment with alum and soda ash

As a result of those high turbidities, we have operated with the addition of alum and very recently of soda ash, the soda ash being introduced at the rate of about half a grain per gallon at the head works, so as to raise the alkalinity of the water which is normally about seven or eight, and in that way obtain an alkalinity of about fourteen.

Dr. Hale made an experiment at the laboratory as to the amount of alum to be used. His samples showed clearly that under laboratory conditions about a grain per gallon was needed. With a grain per gallon you had virtually clear water after standing overnight, whereas with three-quarters of a grain the water would remain at a turbidity of about ten. This turbidity of around one hundred settled out to between twelve and twenty after three or four days standing in a bottle in the laboratory, and then remained at that point virtually continuously for two or three weeks. We have no hope, therefore, of the water clearing up in the reservoir for some time to come. None of us know just how long it will continue with high turbidity.

We cut down the flow through the aqueduct while we were experimenting with the introduction of the alum because we did not wish to take any chance of putting in any large quantity of water in the Kensico Reservoir which was so turbid that it would be unsatisfactory for use. The water flows into the Kensico Reservoir about three miles from the point where it is taken out. It travels through only a portion of the reservoir and, therefore, the full volume of the reservoir is not available for dilution or sedimentation.

During these experiments we have drawn the Kensico Reservoir down about five billion gallons. Now we are delivering about four hundred million a day and taking out about five hundred million, but after the first of the year we expect to go up to a delivery of five hundred or a little above this figure.

As the water now pours into Kensico it has the color of a brownish red paint. Within one hundred feet or so of the point where the water comes in you see a grayish or a greenish gray color to the water and quite a sharply defined line between the turbid water and the water which has shown the effect of sedimentation caused by the addition of the alum. Along the shore where the water comes in, for a distance of several hundred feet, there is a band or strip of red water that represents the current which is created by the flow over the influent weir, but that travels rather quickly along that shore and then slowly moves down the lake. As it moves down the turbidity reduces very rapidly. We believe that we will have no serious difficulty in furnishing a satisfactory water under these conditions, but there is, of course, the possibility that the alum after settling out in the upper part of the basin might sometime later be stirred up through the changes of the water, due to temperature changes or possibly through wind action if the reservoir is low, but I see no reason why the alum should not settle out rather quickly. I doubt very much if we are to have trouble from it. This question will only be finally answered in the future.

Microscopic organisms

As to microscopic organisms in the Ashokan, we may have had a slightly greater number due to the low level at which we carried the reservoir. I remember talking with some of our force when we first started to draw down the Ashokan. The question was: what will happen and will we have any trouble? As nearly as I could see it would simply mean we were changing a big lake into a small one which most of you, if you have a reservoir say of ten thousand million gallons, would say was a fairly good sized reservoir. We never had a reservoir as small as that in the combination of the two basins, but we have had the east basin this year completely empty. It went down to the lowest level at which we could draw water out, and it acted simply as a smaller lake as we drew down the reservoir. We treated both basins with copper for the first time this fall because synura were present. Synura have been present many times before, but this year we were down to a point where it seemed advisable to to treat with copper and the treatment was successful. The B. coli content has naturally been high, but even with the turbidity there has been a complete destruction by the application of chlorine at the head works.

Chlorination

During the summer time we operate another clorination plant at the head of the Ashokan Reservoir, where the water from the

Esopus Creek and the Schoharie Creek flow into the reservoir. That plant was closed in the fall of the year when the summer visitors disappear and the pollution is thereby greatly reduced.

There is a further clorination of the water as it leaves the Kensico Reservoir and at Ashoam and Kensico plants B. coli is absent in 100 cc., except for two or three times during the year, thus showing a high degree of purification. With the turbid water, the same effective purification has been secured at Ashokan. The clay is so finely divided that the chlorine is able to destroy any bacteria. Those clay particles, while very much larger than bacteria, are probably not brought together after they have been washed from their original bed, and I should think that there would be no bacteria concealed in them, as has been shown by a recent test when a sample of treated water was kept for a week, tested daily and showed no B. coli in any test.

Best plan of operation

In the operation of the reservoirs the question arises, where you have two basins such as we have in the Ashokan Reservoir, as to whether it is desirable to keep the west basin full when we have the water there to do so, and let the east basin go down, and then later have the waters coming down the creek flow into the upper end of the basin and let the water flow over the dividing weir into the east basin or to open the gate between the two basins and quickly draw the water from the west basin into the east basin, by the leveling of the waters in the two basins. The east basin could then be held in reserve to let the water clarify, using the west basin water. Later when flood flows come the water could be held back in the west basin as long as possible.

In the Department, some of us are inclined to believe that the better plan is to hold the water in the west basin and let the stream flow raise the water level slightly so it passes over the dividing weir into the east basin, but some believe that the other is the better way.

As the water rises rapidly in a reservoir there is a general stirring up of the contents by the vast amount of work that is done in raising the water level in a large reservoir say 20 feet in a day.

If the reservoir had been at the overflow level at the time of this unusual flood, presumably there would be a general mixture of the waters, but, with the ordinary flood, there certainly will be less work done in the way of producing current, if the excess water is passing over a weir and the water level of the reservoir is raised a foot or two as a whole only, as compared with raising it twenty feet in the course of a day.

The hydraulics of the movement of the water in the reservoir under those conditions would tend to support the theory that better results would be obtained if the water passed from the west into the east basin over the dividing weir.

Generally we have been able to deliver a more satisfactory water each year than the preceding year. That is due in part to the greater experience that has been available as a result of the treatment given the reservoirs with copper sulphate and of the use of excess chlorine to destroy tastes and odors created by the small dose of chlorine destroying the microscopic organism without destroying some of the tastes and odors. It is also due in part to keeping down the turbidity a little more effectively, but generally that has not been a serious problem until now. From now on, with the Schoharie Creek delivering water of much higher turbidity than the Esopus, and especially a turbidity that will not settle out as rapidly, we shall probably have to treat each year for part of the year the entire supply with alum and soda ash. By so doing we probably will be able to give at all times a reasonably clear water without filtration.

DISCUSSION

A. E. Hansen:[3] Mr. Brush, as you know, I am quite interested in designing plumbing systems in New York City. For the past two years we have had a great deal of trouble probably due to the softness of the water from the Ashokan Reservoir, as compared with that in the Croton, so that we have been obliged to use brass pipes in our plumbing systems, especially on the hot water. When you speak about the addition of soda ash and alum, I am wondering whether that would necessitate also brass pipe for our cold water supply in the buildings. It is a very serious proposition to New York City people.

Wm. W. Brush:[2] The probabilities are, Mr. Hansen, that after this season we will not have the low levels in the Ashokan Reservoir. This year was the critical year as far as the economy of lowering the Ashokan Reservoir was concerned. After this year, the average flow

[3] Hydraulic and Sanitary Engineer, New York, N. Y.

from the Esopus and the Schoharie watershed will be in excess of the water that we can take through the aqueduct which has a capacity of 660,000,000 gallons a day. Therefore, in the future, for a little more than half of the years there will be a waste over the Ashokan Dam. With the reservoirs full, we would have a much lower turbidity when the water reaches the intake chamber, and I doubt very much whether we will generally have to add any alum, except for a very short period.

The present time represents probably the longest time that alum will be added and the addition of the soda ash will restore the alkalinity and bring up the pH to about normal for the Catskill water. I would expect therefore that, while there might be for two or three weeks a slight increase in the rate of corrosion from the water that is now in the Kensico Reservoir and is coming through, such condition would not extend for any length of time.

I will ask Dr. Hale to talk a little more on this subject because he is more familiar with it than I am.

Frank E. Hale:[4] The amount of water that has gone into Kensico treated with alum alone is very slight compared to the water in Kensico. We expect that that water will mix with the other water so that the reduction in alkalinity will be very slight. With the soda ash added in equivalent proportion to the alum there should be no change in alkalinity in the water in the city. The alum will not stay in the water. It precipitates out as alum hydrate, as you all know, and will go down into the bottom of the Kensico Reservoir so that, if properly proportioned, the Catskill water will be no more corrosive after this treatment than it has been before.

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[4] Director of Laboratories, Mt. Prospect Laboratory, Brooklyn, N. Y.

PRELIMINARY EXPERIMENTS ON THE TREATMENT OF LAKE MICHIGAN WATER FOR CHICAGO[1]

By John R. Baylis[2]

Experiments at Chicago were started primarily to determine the most efficient method of purifying the Lake Michigan water. With a turbidity that ranges from about 3 to 100 and averages over 10 for some of the intakes, and with pollution that requires a fairly heavy dose of chlorine, the clarity and taste are not all that is desired. Since the construction of the Buffalo filters, Chicago probably has the most turbid water now being supplied any large city in this country, with the possible exception of Milwaukee and Kansas City. The writer, however, has no information on the clarity of the water being supplied these two cities.

The enormous consumption of water in Chicago, together with a supply that is not so very bad, have been the main factors delaying filtration. This paper will not deal with the present quality of the water, or with reasons for starting the experimental work, but with the problems which will receive consideration in the investigation and the results of the experiments already conducted. Mr. John Ericson, City Engineer, and his associates have been considering filtration for some time. It was only after a definite program for filtration had been decided upon that the writer was employed to conduct the experimental work under the direction of Arthur E. Gorman, Chief Sanitary Engineer.

TENTATIVE PROGRAM FOR EXPERIMENTAL WORK

Every method of treatment and every type of filter that offers the possibility of being suitable for Chicago conditions will be investigated. The water must be delivered to the consumer clear, pure and palatable at all times. Palatability will be considered second only to purity and no method will be recommended that does not leave the water clear and palatable.

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[1] Presented before the Illinois Section meeting, January 28, 1927.

[2] Physical Chemist, Division of Water Safety Control, Bureau of Engineering, Department of Public Works, Chicago, Ill.

The tentative program involves such problems as the effect of microörganisms on coagulation, removal of tastes and odors, removal of microörganisms, various kinds of coagulants, optimum chemical conditions for coagulation, the value of mixing in forming a flocculation, types of mixing basins, conditions affecting the strength or toughness of the coagulation, the production of rapidly settling floc, microscopical studies of coagulation, softening, capacity of settling basins, flow through settling basins, rates of filtration, sand sizes, filter underdrains, washing rates, surface wash, prevention of cracks and clogged places, mud balls, and perhaps a few other minor subjects and those which suggest themselves as the work progresses.

Some of the undertakings will prove impractical early in the investigation or of no value in so far as the Lake Michigan water and local conditions are concerned. To illustrate, slow sand filters probably cannot be considered on account of the high cost of land, yet the water probably could be clarified satisfactorily by this method of filtration. The removal of microörganisms is going to be one of the most serious problems with which we will have to deal. There is a limit to the shortness of filter runs beyond which it is not desirable to go.

LENGTH OF FILTER RUNS

When the filter runs are shorter than about sixteen hours they are getting below that period essential for efficient operation. The design should be such that a yearly average of not less than twenty-four hours is obtained between washings, except under unusual conditions. The runs usually should not be less than 16 hours for more than about 5 per cent of the time. It is desirable to have filter runs from forty to fifty hours, but the expenditure of a large sum of money is not warranted to extend the runs much in excess of twenty-four hours.

Lengths of filter runs, as a rule, are not given enough consideration in the design of filter plants, due largely to the fact that most knowledge of the design of rapid sand filters has been worked out at places having fairly turbid water. Coagulation of a fairly turbid water, together with a reasonable period of sedimentation, usually give filter runs in excess of twenty-four hours, which as stated is nearly all that is desired, but in the coagulation of a low turbidity water the problem of preventing short filter runs is not so simple. The time out of service for washing and the amount of wash water are usually the factors receiving most consideration in determining the economical length of filter runs, but the writer is of the opinion that the increase in turbidity of the filtered water after washing is of equal importance. A number of tests at Baltimore[3] show that the turbidity of the filter effluent is increased for a period at least one hour after the filter is put back into service. Should the average increase in turbidity be 1.0 p.p.m. for an hour, which is frequently the case in many filter plants, this would increase the general average of the filtered water by 0.1 with runs of ten hours. When an attempt is made to produce water with a turbidity not over 0.2, this increase is of considerable importance. It may be found that microörganisms are such a problem in the Lake Michigan water that some extreme measure, usually not resorted to in a purification plant, will have to be adopted.

LAKE MICHIGAN WATER EASILY CLARIFIED

The experiments so far conducted indicate that the lake water is easily clarified. Almost any of the extensively used coagulants would be suitable and economical. The water appears to be saturated with soluble silica and alumina and the addition of any amount of alum or iron will produce a precipitate. It is also saturated with calcium carbonate and is ready to precipitate this compound on the addition of a slight amount of lime; that is, it does not require the addition of a definite amount of lime before there is softening effect, as is the case with some waters. The lake water is already partially coagulated and a large percentage of the suspended matter settles out fairly rapidly. Figure 1 shows the character of the suspended matter usually found in the lake water. This condition of partial coagulation may not exist all the time, but the periods within a year's time in which it is in a finely divided state probably are few.

By filtering the water of a turbidity between 10 and 20 p.p.m., without the addition of a coagulant, through an experimental laboratory sand filter, the turbidity is usually reduced to 2 or 3 when using customary rapid sand filter rates. At certain seasons of the year it probably will be reduced still more, although the writer has no hope of it being reduced to the desired standard of 0.2.

The problem of coagulation and clarification appears to be simple, unless the coagulation produced is of such a weak structure that it will readily pass the filter beds in the colder months, as at a number of filter plants. The problem is not going to be whether alum, iron and lime, or lime alone will clarify the water, but which of the methods will be the most economical for Chicago. Either of the three methods will remove the turbidity to the desired standard.

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[3] Baylis, This Journal, 15: 673, June, 1926.

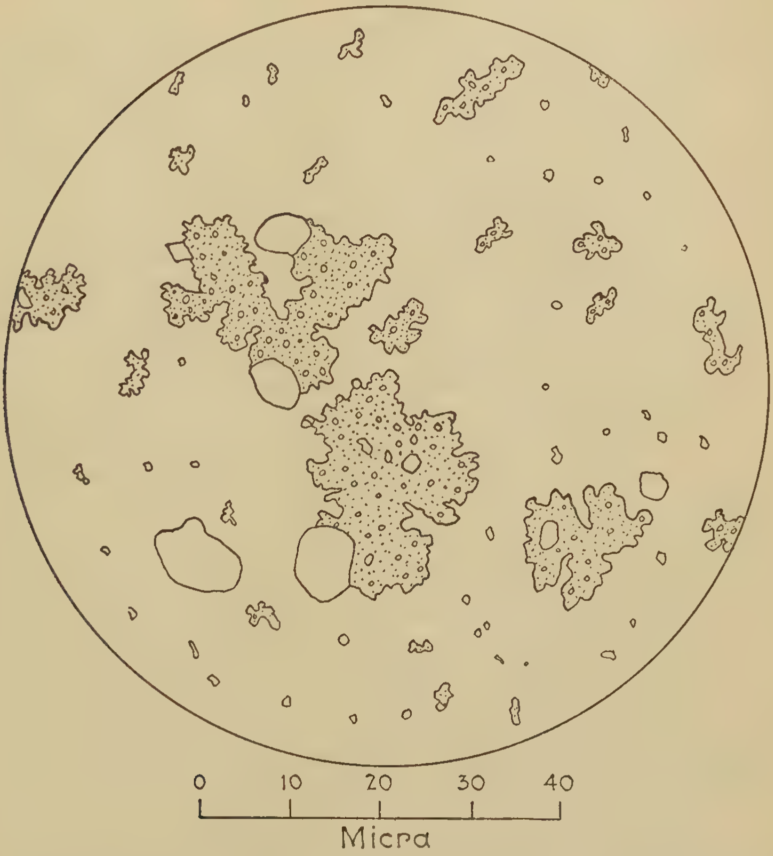

FIG. 1. CAMERA LUCIDA DRAWING OF SUSPENDED MATTER IN THE LAKE MICHIGAN WATER

The turbidity was 38 p.p.m., most of which was composed of partially coagulated masses of the finer particles. This is probably due to a supersaturation of some compound in the water such as silica or alumina.

STANDARD FOR CLARITY

Several years ago the writer[4] expressed the opinion that a properly coagulated water should filter to a turbidity of 0.2. This was based upon experiments using the Gunpowder River water at Baltimore. Plotting the quantity of coagulant used against the turbidity of the filter effluent, there appeared to be a sharp break in the curve indicating the economical point to be at a turbidity of about 0.2 (See Eng. News-Record, 92: 768, May 1, 1924). Later it was found that the break may be as low as 0.1 turbidity in many instances, but rarely ever above 0.2. Close attention has been given by the writer to the clarity of water which will not cause complaints or be noticed by the consumers. The noticeable point in bathtubs and other vessels of water likely to be observed by the average person is a turbidity of 0.5. To prevent frequent surpassing of this figure under normal operating conditions it has been found that the aim should be a turbidity of 0.2, with clarity alone under consideration. It was also found that there was better bacterial removal when the turbidity was lower than 0.5. When considered from the standpoint of bacterial removal it is usually desirable to reduce the turbidity as low as is practicable.

Experiments on the Lake Michigan water so far indicate this same sharp break in the curve to be between turbidity of 0.1 and 0.2. A turbidity of 0.2, after filtering through a standard sand bed, which will be described later, has been tentatively set as the desired standard for clarity. The theoretical quantity of coagulant is that which will produce this standard after filtration. All experimental work will be based on the standard, unless it is found at some later date that another figure should be used. In other words, no treatment will be regarded as satisfactory that does not reduce the turbidity to 0.2.

LABORATORY SAND FILTER

In 1924, the writer constructed a laboratory sand filter as shown in figure 2. The size of tube, thickness of glass, depth of sand, size of sand, etc., were decided upon after experimenting with various modifications. This was found to duplicate very well the large filter beds at the Baltimore filter plant. From the knowledge gained by conducting a large number of experiments in the laboratory, where

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[4] This Journal, 11: 824, July, 1924.

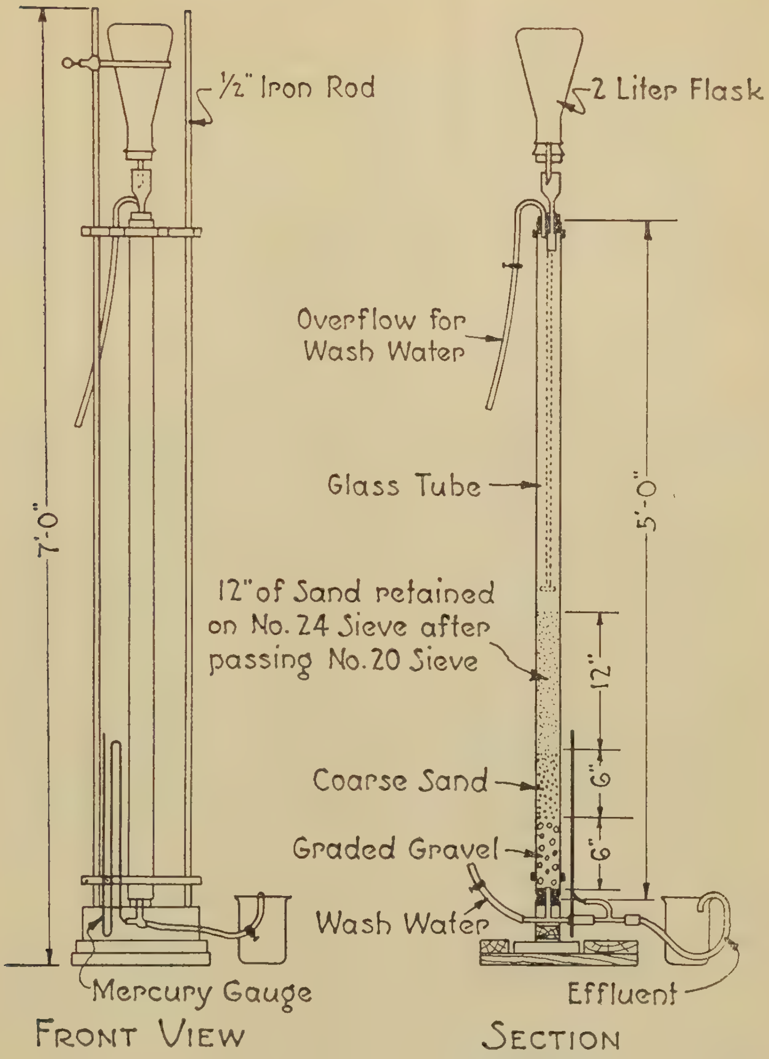

FIG. 2. LABORATORY SAND FILTER

the results could be checked on a plant scale, it was learned how to interpret the laboratory experiments very accurately. The bulk of the Chicago experiments will be made with such a filter.

An experimental plant with a capacity of about 500,000 gallons daily will be constructed in the early spring so that laboratory experiments may be checked in an actual plant. For the number of experiments contemplated it would be out of the question both in cost and time to conduct them on so large a scale even as the experimental plant. Perhaps one surprising thing about the laboratory filter is the large size sand used (about 0.8 mm. for the 10 per cent size). Finer sand than this always gave better results than did the large beds at Baltimore, and it was not until sand of about 0.8 mm. size was tried that there was duplication of plant results. Taking into consideration the fact that the surface of a filter bed is usually never perfect, and that cracks or holes are usually formed in the surface layer after the bed has been in service for a few hours after washing, it is readily seen that reliance is not placed on the fine sand near the top of most filter beds for removing all of the suspended matter. In the experimental work it is planned to keep one laboratory sand filter with a standard sand, and to have one or more such units in which variations from the standard will be tried.

These filters may be adapted to almost any condition. They can be placed on the floor and all heads made positive, or they can be placed on a stand or table of any desired height, with the effluent tubes leading to the floor. In this way negative head may be introduced to the same extent as in a large filter plant. By raising the flask and funnel any head desired may be obtained. In this case the funnel is connected to the filter with a small glass or rubber tube. The filters may be placed in rooms of variable temperatures for testing the effect of temperature. They also may be connected to the influent of the large filters and comparisons made. The variety of conditions under which the laboratory filter may be operated gives an opportunity for conducting a large number of experiments at a low cost. Extreme conditions, frequently necessary for definite proof of some specific factor, are easily produced, whereas it may be impossible in a large filter. Many points on a curve may be established with the laboratory filter, and then with a few points on a large filter bed the trend of the curve for plant conditions may be predicted with considerable accuracy.

STIRRING MACHINE

The stirring machine shown in figure 3 is as important as the laboratory filter. The writer has used a similar machine for several years and finds it to be almost indispensable for studying coagulation. As agitation materially aids certain chemical reactions, it especially applies to the formation of a coagulation in water treatment. Each stirrer of the machine has 2 blades, $\frac{1}{2}$ by $1\frac{1}{2}$ inches, fastened to the lower end of a $\frac{3}{8}$ inch brass rod which slides up and down in a hollow shaft so as to clear the top of the beakers. Two-liter beakers will be used for most of the experiments, although larger or smaller vessels may be used if desired. Adjustable rubber wheels drive the discs at the top of the shafts at any speed between 60 and 300 revolutions per minute. The time of stirring has great influence on the formation of the floc, which largely controls the rate at which it will settle in the settling basins. A rapid settling floc may be desirable for removing microörganisms by sedimentation so as to prevent most of them from going on to the filter beds, and the effectiveness of coagulation in precipitating microörganisms can be studied thoroughly with the aid of the stirring machine.

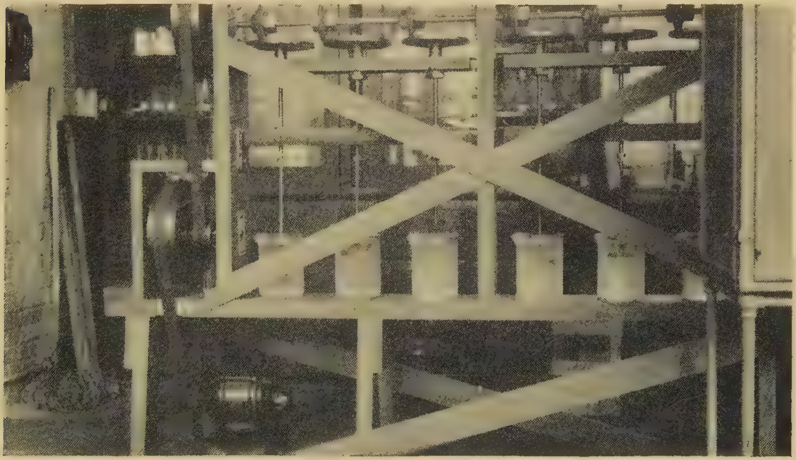

FIG. 3. STIRRING MACHINE

At Baltimore, it was found that, with a certain time of stirring at a certain speed, the coagulation approximately duplicated that produced in the mixing basin. This proved to be advantageous in experimental work, for, with the laboratory filter, plant conditions could be duplicated in the laboratory. The laboratory stirrer and filter were used extensively at Baltimore in keeping the coagulant at a minimum. When the only means of telling if the coagulant may be reduced is to reduce it and run the risk of getting cloudy water through the filters, the operator naturally hesitates to reduce unless it is evident that considerable excess is being added. The day is approaching when methods now in use for determining the quantity of coagulant to apply in a filter plant will be regarded as crude and wasteful of chemicals.

After the experimental plant in Chicago is constructed and in operation, its efficiency will be checked with the laboratory apparatus. If it is found that there is considerable difference in the results obtained it may be desirable to change or extend certain parts of the experimental plant. The plant is being designed with greater flexibility than has ever before been attempted for an experimental plant.

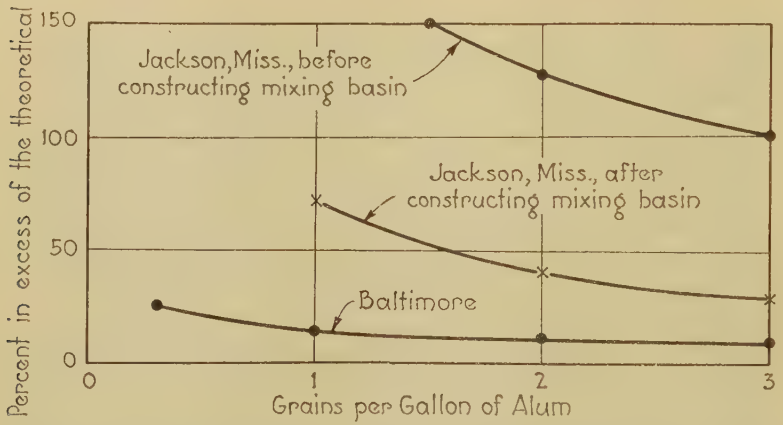

Fig. 4. Excess of Alum in Plant Operation over the Theoretical Quantity Necessary to Clarify the Water

It is hoped that the laboratory results can be duplicated with considerable accuracy. The minimum quantity of chemicals necessary to clarify and perhaps to soften the water will be determined in the laboratory with the stirring apparatus and the laboratory filter. This will require operating the experimental plant under extreme conditions for part of the experiments, conditions that are known not to be economical for a large plant, but it is only from such information that the most economical layout of the large plant may be determined.

Should it take only 0.2 of a grain per gallon of alum to clarify a turbidity of 20 in the laboratory and 0.4 in a filter plant, it would be evident that the layout of the plant was not efficient. Some plants show considerable difference between the theoretical, as determined by the laboratory apparatus, and the actual amount used. A great many plants have been designed only to produce clear water and no one has any idea whether the layout is efficient or not. What is now needed in filtration practice is a procedure for accurately determining in the laboratory the minimum quantity of coagulant necessary to produce the desired clarity and bacterial removal for a given water. When plant results deviate greatly from the theoretical an effort should be made to improve conditions.

These facts are illustrated in figure 4. The mixing basin at Baltimore, which has a period of nearly thirty minutes mixing at rated capacity, is believed to be an efficient basin for aluminum sulfate. The excess of alum in plant operation required over the minimum, as determined with the laboratory stirrer and filter, varies from about 25 per cent for 0.3 grain per gallon to about 10 per cent for 3.0 grains. In this case the laboratory samples were stirred for forty-five minutes. The excess is in addition to about 10 per cent always allowed for fluctuations in the strength of the alum solution and in the controlling apparatus. A longer mixing period in the plant at Baltimore may reduce the excess slightly, but the mixing basin as now constructed approaches the economical limit. Perhaps it should be mentioned that the basin was designed for the use of iron and lime and was made for a longer period of mixing than is usually considered necessary for alum. Compare this with the alum used in the filter plant at Jackson, Miss., in 1915 and 1916.[5] This plant was originally constructed with little mixing, but a small mixing basin was added in 1916. The curves for Jackson are only approximate, for the writer stirred the samples by hand, filtered through paper, and had no accurate turbidimeter. The results, however, are not far from correct. The addition of a short mixing basin reduced the amount of alum materially, but it was still a considerable distance from the theoretical.

COAGULATING WITH ALUMINUM SULFATE

The Lake Michigan water is easily coagulated with aluminum sulfate. The reason for this has not as yet been definitely determined, but, as stated, there are indications that the water is already saturated with soluble alumina and the addition of any amount of alum, however small, produces a precipitate. It is also probable that the nature of the suspended matter has considerable influence. Since most of the rain water in the vicinity of Chicago is discharged through the Chicago River and the Drainage Canal to the Illinois River, there is not much fine suspended matter entering the lake at this point. Turbid water from wave action near the shore is constantly being taken out of the lake through the canal. Most of the turbidity in the section near the intakes is caused by wave action picking up the suspended matter precipitated at some previous time. Samples of the turbid lake water stored in bottles usually coagulate and settle to a turbidity of less than 5 within twenty-four hours; that is, the small coagulated masses shown in figure 1 have a tendency to unite into larger particles which are approximately the size of aluminum hydroxide floc. The suspended matter since the experiments were started appears to be composed of a turbidity of 3 to 10 parts of fine suspended matter and the balance is in masses of partially coagulated particles. It is likely that the amount of fine turbidity, which most of the time has ranged near the lower figure, largely determines the amount of alum necessary to clarify the water.

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[5] Baylis, Eng. News-Record, 80: 364, February 21, 1918.

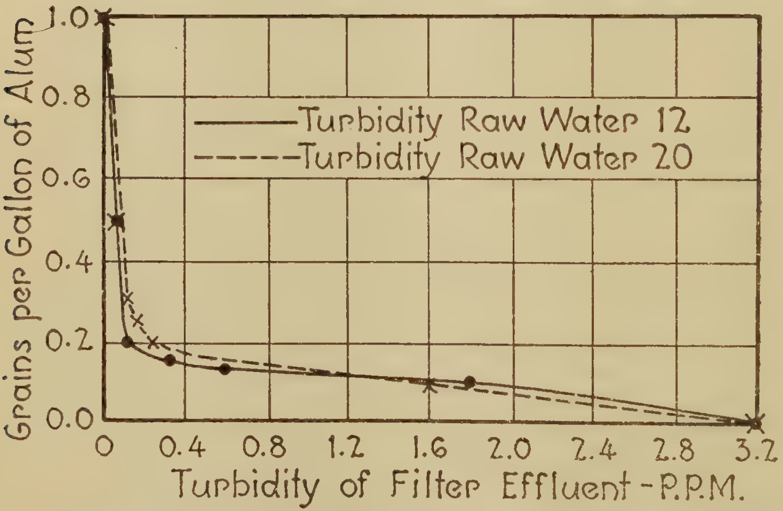

FIG. 5. CLARIFICATION PRODUCED BY VARIABLE QUANTITIES OF ALUM; THIRTY MINUTES STIRRING

The curves in figure 5 are about the average of conditions for fairly low-turbidity water. This is after filtering through the laboratory sand filter which had sand that was retained on a No. 30 sieve after passing a No. 20. Two-tenths of a grain per gallon of alum at the time the experiments were made appears to be approximately the theoretical amount for clarifying the water to a turbidity of 0.2. This is probably much less alum than is being used in most plants filtering the Great Lakes water to this clarity. It is also less than would be necessary for a large plant in Chicago. The economical layout of a well designed plant should not exceed the theoretical by more than about 25 or 30 per cent; that is, when the theoretical amount is 0.2 grain per gallon, a large plant should use somewhere between 0.25 and 0.3 grain.

The above applies to the coagulant necessary only to clarify the water. During periods when microörganisms are in abundance, it may be found advisable to use more coagulant so as to precipitate a large percentage of the organisms in the settling basins. Treatment with aluminum sulfate would make the water slightly more corrosive, but not to an objectionable extent. The sulfate hardness would also be increased in proportion to the alum used, but there would be no change in the total hardness. If microörganisms were not a factor and there was nothing to be gained by softening, there would be little doubt about alum being the most economical chemical to use. The ease, however, with which some of the hardness may be removed from the water is a factor well worth considering.

IRON AND LIME

The lake water responds readily to treatment with iron and lime in the laboratory and, due to the softening effect, this treatment may prove to be very economical. The curve in figure 6 shows what may be accomplished with variable quantities of iron when 2 grains per gallon of lime (CaO) are used. A very good coagulation can be obtained with iron when any quantity of lime in excess of about 0.5 grain is used. The economical amount of lime will depend on its softening value. The reduction in hardness is fairly rapid for small quantities of lime and it certainly would be desirable to use at least 2 grains. Experiments indicate that the hardness will be reduced at least 35 parts per million with this amount, which is a reduction of about one grain of hardness per grain of lime used. Certainly this reduction is well worth while.

It may be desirable to use more than 2 grains of lime, but this is getting near the point where it would be necessary to carbonate the water in order to produce a satisfactory product. The upward trend in the total hardness as the amount of iron used is increased, shown in figure 6, indicates that it is desirable to have very efficient coagulation. This will require considerable attention to the design of the mixing basin. Mr. C. Arthur Brown has always been an advocate of prolonged mixing, together with a certain violence of the agitation to produce the best results with iron. The writer agrees with Mr. Brown.

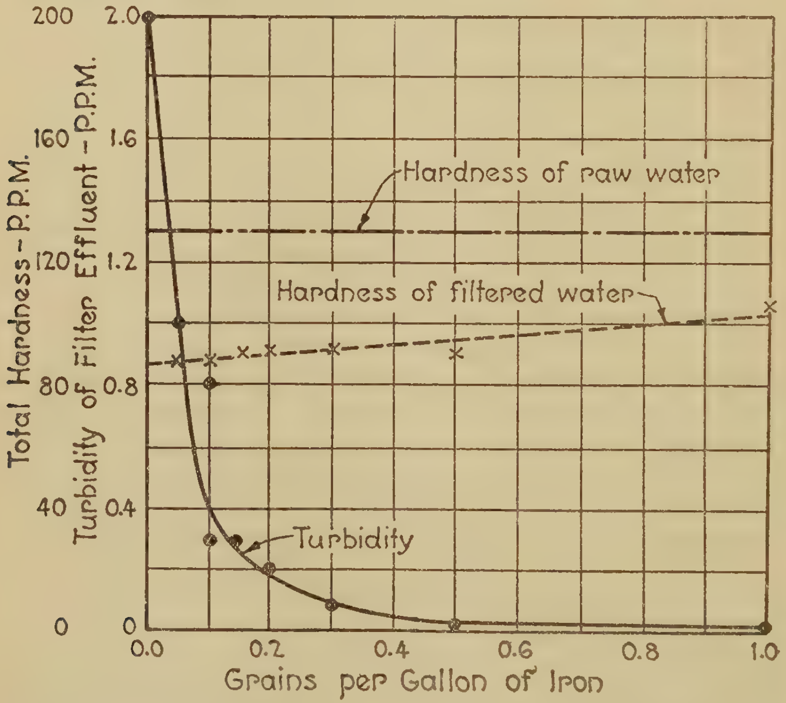

FIG. 6. CLARIFICATION PRODUCED BY VARIABLE QUANTITIES OF IRON, 2 G.P.G. LIME (CaO), STIRRED THIRTY MINUTES, TURBIDITY RAW WATER, 12 P.P.M.

LIME FOR SOFTENING AND CLARIFICATION

The excess lime treatment is now being used for certain hard waters where it is desirable to soften for boiler uses. This leaves the water with some caustic alkalinity, and it is not satisfactory for domestic supplies unless the caustic alkali is changed to the carbonate or bicarbonate. Within the past few years recarbonating highly alkaline waters has been demonstrated to be a success for municipal supplies, probably being tried out first at Defiance, Ohio.[6] This opens up a new field in the softening of certain hard waters. Mr. C. P. Hoover of Columbus, Ohio, perhaps has done more than any one else in contributing to our knowledge of the softening of municipal water supplies, and much of the success in extending the excess lime treatment and recarbonization to municipal supplies has been due to his efforts.

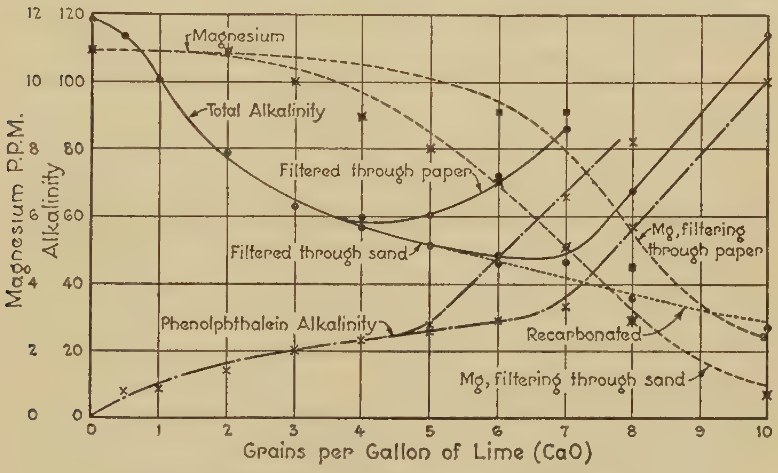

FIG. 7. RESULTS OF TREATMENT WITH LIME

The Lake Michigan water has a total hardness of about 130 parts per million, nearly all of which is carbonate hardness. This is not very hard and is at the point where it is doubtful if the excess lime treatment would be economical. The lake water is always near the equilibrium point of calcium carbonate and the addition of any quantity of lime in excess of about 0.2 grain per gallon forms some calcium carbonate precipitate and leaves the water softer after filtration than before treatment. The addition of lime up to about 3 grains (pure CaO) softens at approximately the rate of one grain of hardness per grain of lime, but beyond this point the rate drops off. Recarbonization is essential either before or after filtration when over 2 grains of lime are used, and this will hold up to the point where caustic alkalinity starts. Beyond this the caustic alkalinity at least should be carbonated before filtration and the filter effluent should then be carbonated to nearly the solubility equilibrium of calcium carbonate.

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[6] Hill, This Journal, 7: 440, July, 1920.

When about 6 grains of lime are added, magnesium hydrate begins to precipitate in quantities that will coagulate the suspended matter in the water. The precipitate formed is heavy and settles rapidly. The water then, after recarbonating, will filter perfectly clear. With less than about 5 grains of lime a coagulant for removing the suspended matter probably will be essential. The curves in figure 7 show about what may be accomplished with the excess lime treatment. The use of 10 grains of lime reduces the magnesium to about 3 parts of Mg, but it is evident that recarbonating so high a caustic alkalinity is beyond the economical point for domestic supplies. It does show, however, what may be accomplished in industrial uses where it is desirable to reduce the magnesium as well as the calcium. It would be possible to reduce the total hardness of the Lake Michigan water to about 40 parts per million should some industrial process require such a soft water, but this is somewhat less than is practical on a large scale. The following experiment is about an average of what has been accomplished in the laboratory:

Raw water

Turbidity 10, alkalinity 118, pH 8.0, total hardness 130.

Treated with 10 grains per gallon of lime (pure CaO), stirred twenty-five minutes in the stirring machine, and decanted after settling thirty minutes. About 95 per cent of the precipitate settled out.

Filtering through paper the phenolphthalein alkalinity was 120 and the methyl orange alkalinity 130.

The sample was carbonated, allowed to stand one hour, and then filtered through the laboratory sand filter.

Filtered water

Turbidity 0.00, phenolphthalein alkalinity 10, methyl orange alkalinity 27, soap hardness 36, calcium (Ca) 9.9, magnesium (Mg) 3.3, total hardness by computation from the amount of magnesium and calcium present 39.3.

Should the excess lime treatment prove to be desirable for Chicago, about 6 grains of lime would be the most desirable quantity to use. By settling out the heavy precipitate in a small settling basin and carbonating the caustic alkalinity before passing the water through fairly large settling basins, the total hardness may be reduced to about 50 parts per million in a large size plant. In this case probably one-third of the magnesium would be removed, which would leave the calcium-magnesium ratio somewhat out of the proportions usually found in natural waters, but this probably would be of little consequence. The excess lime treatment would solve filter clogging troubles from microörganisms, would produce a clear and palatable water, and the treatment is generally thought to have considerable sterilizing value. The sulfate hardness would not be increased, if lime reasonably free from SO_3 is used. The chief advantage of the treatment is reducing the hardness to such a low point, but the cost of construction and operation may be so great that a partially softened water would be more economical.

The writer wishes to express his appreciation of the valuable suggestions made by Frank Hannan of Toronto on the possibilities of the excess lime treatment for clarifying and softening the Great Lakes water.

DISCUSSION

W. R. GELSTON: When we tried excess lime treatment at Quincy there was trouble with clogging of sand beds and filling of pipes with lime.

JOHN R. BAYLIS: It is best to carbonate before filtering. Otherwise some of the softening takes place after passing the filter bed.

W. R. GELSTON: We had only one hour of sedimentation at Quincy.

C. P. HOOVER: The author is to be congratulated upon the paper. The use of excess lime together with carbonation is a new method of procedure in softening. It is possible to make the water so clear and the load on the filters so light that the filters might be run at three times the ordinary rate of filtration.

G. C. HABERMEYER: Filtering at rates of 4 or 5 gallons per square foot per minute would make friction losses high.

W. LUSCOMBE: Have you considered extending intakes further into the lake instead of filtering?

John R. Baylis: To get water fairly free from turbidity we must get the water at a depth of 40 to 50 feet and that would require intakes ten miles farther from shore. During a recent investigation we found that turbidity extends from shore to distances of 12 to 14 miles after storms, and that microörganisms were high. Three or four cyclops per liter were found 12 miles from shore.

A. M. Buswell: Have you made studies concerning the disposal of sludge? Lime treatment of sewage sludge has been found beneficial.

A. V. Graf: At Detroit 6 million gallons per day are filtered through beds designed for 4 millions. Sand grains became encrusted. Cyclops are more frequent at great depths. At St. Louis there have been so many at the bottom of 35 foot basins that the sludge on the bottom has been kicked up to make clouds of turbidity.

FLOOD CONTROL IN THE MIAMI VALLEY OF OHIO[1]

By C. S. Bennett[2]

The Miami River drains the southwestern portion of the State of Ohio. Its source is in Logan County just west of the center of the state, and it empties into the Ohio River at Cleves, a few miles below Hamilton. The total length of its winding course is 163 miles. The important tributaries of the Miami above Hamilton are Four Mile, Seven Mile, Twin, and Wolf Creeks, the Stillwater River and Loramie Creek from the west, and Mad River from the east. Wolf Creek and Stillwater and Mad Rivers join the Miami in the City of Dayton. The Miami drainage area is about 120 miles long. Its area above Hamilton is 3672 square miles and above Dayton, 2600 square miles. The slopes are short and steep, the grades of the main streams rather flat. While draining of swamp lands, tiling, cultivation of farms, and possibly the destruction of the forests have slightly increased the flood runoff, the tremendous floods that sweep down the valley are due primarily to the great storms which occur at intervals in this section of the United States.

First settled about 1790, the Miami Valley has grown to be a prosperous community with numerous busy towns and rich farm lands. The towns have, in general, grown up along the streams and the old Miami and Erie Canal, which were the first means of transportation, and consequently these towns are in the overflow channel of the river in many cases. The history of the valley is replete with accounts of serious floods, culminating in the great disaster of 1913. In the past, more or less inadequate levees had been built around the towns, but until after the flood of 1913, no comprehensive plan for making the valley safe had ever been adopted.

THE 1913 FLOOD

A tremendous storm swept the Miami Valley from March 23 to 27, 1913. It caused the most severe flood that had ever been known in that valley,—in fact, the greatest flood, as regards damage, that has yet occurred in the eastern half of the United States. For five days the rain continued; the total precipitation averaged around 10 inches over the watershed above Dayton. The ground was saturated and partly frozen, so that the runoff from this great rainfall was very considerable,—practically 100 per cent during the latter part of the storm.

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[1] Presented before the Indiana Section meeting, February 8, 1927.

[2] Engineer, The Miami Conservancy District, Dayton, Ohio.

In the building of cities, railroads, and bridges, and in locating improvements near rivers, the usual high-water stages are taken into account. It has frequently been assumed that past floods, with perhaps a little estimated increase, are a reliable criterion of what may happen in the future. The fallacy of this reasoning for districts where records are available only over short periods, was well illustrated in the Miami Valley during the flood of 1913. Levees and bridges had been built there to accommodate the largest flood that had occurred during the forty years or so that records were available. The water in Dayton during the crest of the 1913 flood stood about six feet higher than the tops of those levees. Not a bridge across the river was passable, many of them were washed out entirely. Nearly four times as much water came down the river as the leveed channel could carry. Large parts of the business and residential districts of the city were overflowed to depths up to twelve feet. Similar conditions existed in the other cities and towns throughout the valley.

Thousands of people were marooned for three days and nights in the attics and on the roofs of their dwellings. Over 400 lives were lost. Property loss has been estimated at about $100,000,000, not including the indirect losses, such as interruption of business, loss of time, depreciation in property values, illness to many people as a result of exposure and shock. Fires added to the destruction in Dayton and Hamilton. Many bridges were wholly or partially destroyed; great areas of street paving were damaged or entirely washed away; mud and silt were deposited in layers in houses, offices and factories; transportation facilities were entirely disrupted. The communities of the valley were prostrated by the calamity.

ORGANIZATION FOR FLOOD CONTROL

The flood waters had hardly subsided before relief committees were organized in the different cities of the valley. At first the work of the committees was confined to emergency help to the flood sufferers, but within sixty days after the disaster, and while the people were still overwhelmed with the problems of their personal losses, the citizens of Dayton alone raised a fund of $2,000,000 for the purpose of making the necessary surveys and studies to work out a flood prevention program. More than 23,000 individuals contributed to this fund.

At first each community in the valley approached the problem independently, the thought being that protection could be secured by channel improvement and levee construction through each city. As the investigations progressed it became apparent that the difficulties in securing a satisfactory solution to the big problem were so great that the individual communities could not meet them separately, and that coöperative action of the entire valley was necessary.

The investigations of the engineers indicated that channel improvement alone was impracticable, and the next thought was for retarding basins. Further considerations brought the conclusion that a combination retarding basin—channel improvement plan would best meet the situation, and the project was worked out through the coöperation of all of the communities in the valley in one comprehensive plan.

Under the Ohio laws there was no practical way for the people to organize for this particular purpose, and it became necessary therefore to enact legislation which would provide for such organization. The Conservancy Act of Ohio, passed in 1914, was the result of this effort. Through the provisions of this law a community may, by petition, organize a District for flood control purposes. Provisions are made for the necessary preliminary investigations, submission and adoption of a plan, appraisal of properties affected, levying of assessments for carrying out the plan, issuance and sale of bonds to provide immediate funds, and other steps necessary for the construction and maintenance of the works of the District. Figure 1 indicates the sequence of steps preliminary to the construction of a flood control project. The arrows in each case start at the party taking the action and point to the party with whom the action is taken. For example, beginning at the upper left hand portion of the diagram and following the first two arrows from left to right, it will be seen that action under the law is started by the property owners filing a petition and bond with the Court. Following the third arrow from right to left, it appears that the Court then publishes notice of a hearing on the petition. Next the property owners may file objections with the Court to the organization of the District, as indicated by the fourth arrow, and so on.

The fundamental principles involved in the law are few and simple. The Court of Common Pleas exercises the primary functions in the proceeding. The Directors, who are appointed by the Court and act as the business managers of the District, handle all of the details of the organization and construction of the works. The appraisers are appointed by the Court. Their job is to make an appraisment of all benefits and damages to property affected by the proposed construction, and it is upon their appraisal of benefits that the assessments for construction and maintenance purposes are based. All expenses incidental to the carrying out of the program of a District are met by a a direct levy on the properties and communities actually benefited by the work. In anticipation of the collection of these assessments, bonds may be issued to provide immediate funds.

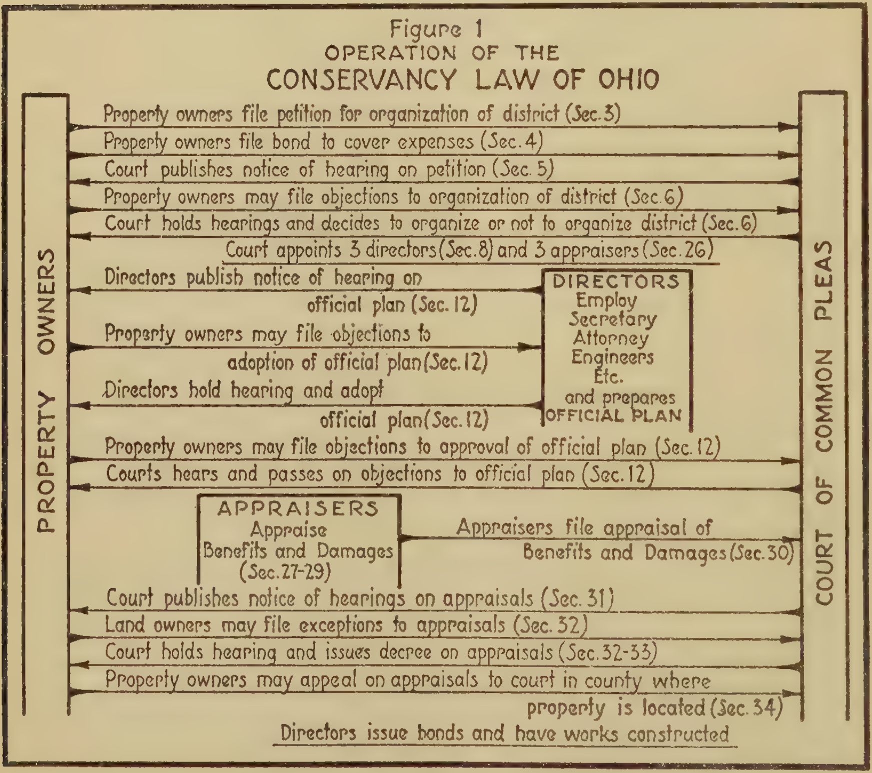
Figure 1
OPERATION OF THE
CONSERVANCY LAW OF OHIO
PROPERTY OWNERS
COURT OF COMMON PLEAS
Property owners file petition for organization of district (Sec. 3)
Property owners file bond to cover expenses (Sec. 4)
Court publishes notice of hearing on petition (Sec. 5)
Property owners may file objections to organization of district (Sec. 6)
Court holds hearings and decides to organize or not to organize district (Sec. 6)
Court appoints 3 directors (Sec. 8) and 3 appraisers (Sec. 26)
Directors publish notice of hearing on official plan (Sec. 12)
DIRECTORS
Employ
Secretary
Attorney
Engineers
Etc.
and prepares
OFFICIAL PLAN
Property owners may file objections to adoption of official plan (Sec. 12)
Directors hold hearing and adopt official plan (Sec. 12)
Property owners may file objections to approval of official plan (Sec. 12)
Courts hears and passes on objections to official plan (Sec. 12)
APPRAISERS
Appraise
Benefits and Damages
(Sec. 27-29)
Appraisers file appraisal of Benefits and Damages (Sec. 30)
Court publishes notice of hearings on appraisals (Sec. 31)
Land owners may file exceptions to appraisals (Sec. 32)
Court holds hearing and issues decree on appraisals (Sec. 32-33)
Property owners may appeal on appraisals to court in county where property is located (Sec. 34)
Directors issue bonds and have works constructed

FIG. 1

THE DEVELOPMENT OF THE PLAN

The Miami Conservancy District was established by the Court in June, 1915. During the time that elapsed while the legislation was being worked out and finally passed, the engineers employed by the citizens had completed their studies and investigations to the point where a complete plan could be outlined. Fortunately, the engineers were called in shortly after the flood, when high-water marks and other desirable records were still available. The great quantity of data collected included typical cross-sections of old channels; levee profiles; cross-sections of the valleys at controlling points; surface slopes during the peak of the flood; size of bridge openings; time of flood crest at different places; velocity of flood flow; rainfall and runoff data; information on past floods in the Miami Valley and elsewhere; topographic surveys.

As soon as sufficient data had been obtained, studies and computations were made. These included studies of flow in open channels; determination of the value of "n" in Kutter's formula, under various conditions; computations of peak flow and total discharge, at various points, during the 1913 flood; study of shape, size and character of the drainage area; determination of the maximum possible flood; study and investigation of various methods of flood control; estimates of costs of various flood control plans. As soon as the retarding basin scheme became a possibility, other questions presented themselves, among the more important of which were the determination of the location, size and number of dams; tentative channel capacities through the cities; determination of height of dams and size of conduits; backwater effects and curves; spillway capacities; balancing of retarding basin capacities, outlet capacities and channel capacities; and finally, a determination of public and private property affected; valuations of properties as to damages and benefits; preliminary estimates of cost.

The so-called "Official Plan," which indicated the exact methods to be used in securing the necessary flood protection, together with the volume and character of work required, types of structures and estimates of cost, was presented to the Court by the Board of Directors of the District, and was approved by the Court late in 1916.

Meanwhile the three appraisers appointed by the Court began to determine for all real property and for the communities as a whole, the benefits which result from the construction of protection works.

About one half of the total benefits was assessed to the cities and counties as a whole. These are in proportion to the degree that a flood equal to that of 1913 would affect them as communities. The other half of the benefits was assessed to the individual pieces of property subject to actual flooding. The value of the property, degree of protection needed and provided, depth of flooding in the 1913 flood, were all taken into consideration in assessing the benefits. For example, a property subject to flooding ten feet deep was assessed a larger percentage of its value than one subject to only three-foot flooding. That is to say, each property was assessed in accordance with the degree of benefit to be received. There were about 70,000 pieces of property affected. When the benefits were added up they totalled about $77,000,000.

The construction was paid for from the proceeds of the sale of $33,890,909.83 worth of bonds, secured by the benefits appraised and representing approximately 45 per cent of the total benefits. The bonds will be retired by 1949, a portion being taken up each year. The money to take up the bonds, to pay the interest on the bonds, and to pay for the maintenance of the works, is provided by a tax against the benefited property. Since about one-half of the total benefits was assessed against the cities and counties of the District, about one-half of the yearly tax is levied against all of the property in the cities and counties. The other half is levied against the properties protected against actual flooding in proportion to their benefits.

In addition to the establishment of the benefits, the damages caused by the proposed works were set by the appraisal board. Rights of way were obtained, and the rights to flood the lands in the retarding basins were secured. As these lands are still available for agriculture, a portion of the land owners elected to sell a flood easement to the District. Others, uncertain as to the effect of the basins on their property, sold their holdings outright to the District. About 30,000 acres were so purchased. These lands are being resold with a flood easement attached.

DESCRIPTION OF PROJECT

The map of the District (fig. 2) shows the principal features of the flood control project. Before the "Official Plan" was adopted many schemes had been studied and discarded as not practical, or as too expensive. The diversion of Mad River into the Little Miami, the building of by-passes for carrying the water around the cities, channel

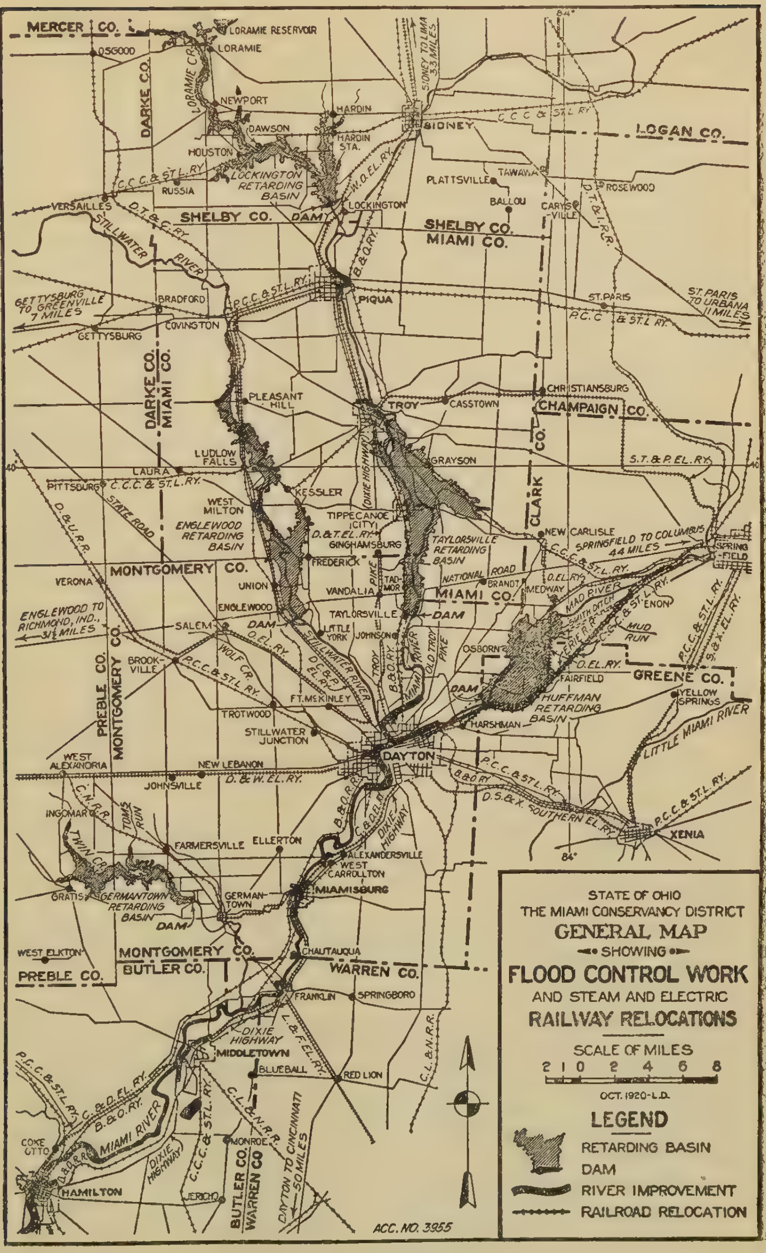
STATE OF OHIO
THE MIAMI CONSERVANCY DISTRICT
GENERAL MAP
SHOWING
FLOOD CONTROL WORK
AND STEAM AND ELECTRIC
RAILWAY RELOCATIONS
SCALE OF MILES
2 1 0 2 4 6 8
OCT. 1920-L.D.
LEGEND
RETARDING BASIN
DAM
RIVER IMPROVEMENT
RAILROAD RELOCATION
ACC. NO. 3955
MERCER CO.
LORAMIE RESERVOIR
LORAMIE
OSGOOD
DARKE CO.
LORAMIE CR.
NEWPORT
HARDIN
HARDIN STA.
DAWSON
SIDNEY
SIDNEY TO LIMA 33 MILES
C.C.C. & ST.L. RY.
LOGAN CO.
HOUSTON
LOCKINGTON RETARDING BASIN
RUSSIA
VERSAILLES
LOCKINGTON
DAM
W.O. EL. RY.
PLATTSVILLE
TAWAWA
ROSEWOOD
BALLOU
CARYSVILLE
D.T. & I. R.R.
SHELBY CO.
SHELBY CO.
MIAMI CO.
STILLWATER RIVER
D.T. & C. RY.
B. & O. RY.
PIQUA
ST. PARIS
ST. PARIS TO URBANA 11 MILES
P.C.C. & ST.L. RY.
GETTYSBURG TO GREENVILLE 7 MILES
BRADFORD
COVINGTON
GETTYSBURG
DARKE CO.
MIAMI CO.
PLEASANT HILL
TROY
CASSTOWN
CHRISTIANSBURG
CHAMPAIGN CO.
LUDLOW FALLS
GRAYSON
S.T. & P. EL. RY.
LAURA
PITTSBURG
C.C.C. & ST.L. RY.
STATE ROAD
D. & U. R.R.
KESSLER
WEST MILTON
DIXIE HIGHWAY
CLARK CO.
TIPPECANOE (CITY)
D. & T. EL. RY.
ENGLEWOOD RETARDING BASIN
GINGHAMSBURG
TAYLORSVILLE RETARDING BASIN
NEW CARLISLE
SPRINGFIELD TO COLUMBUS 44 MILES
SPRINGFIELD
VERONA
MONTGOMERY CO.
FREDERICK
PIKE
NATIONAL ROAD
BRANDT
C.C.C. & ST.L. RY.
O. EL. RY.
UNION
VANDALIA
TADMOR
MIAMI CO.
MEDWAY
MAD RIVER
ENGLEWOOD
TAYLORSVILLE
DAM
SMITH DITCH
ERIE R.R.
ENON
ENGLEWOOD TO RICHMOND, IND., 31 MILES
SALEM
DAM
O. EL. RY.
LITTLE YORK
JOHNSON
OSBORN
MUD RUN
PREBLE CO.
MONTGOMERY CO.
BROOKVILLE
WOLF CR.
D.C. & P. EL. RY.
STILLWATER RIVER
TROY
B. & O. RY.
MIAMI RIVER
OLD TROY PIKE
O. EL. RY.
FAIRFIELD
GREENE CO.
P.C.C. & ST.L. RY.
D.S. & X. EL. RY.
P.C.C. & ST.L. RY.
FT. MCKINLEY
DAM
HUFFMAN RETARDING BASIN
YELLOW SPRINGS
TROTWOOD
HARSHMAN
LITTLE MIAMI RIVER
STILLWATER JUNCTION
DAYTON
WEST ALEXANDRIA
NEW LEBANON
D. & W. EL. RY.
B. & O. RY.
P.C.C. & ST.L. RY.
D.S. & X. SOUTHERN EL. RY.
JOHNSVILLE
C.N. R.R.
INGOMAR
TOMS RUN
B. & O. R.R.
C.& D. EL. R.R.
DIXIE HIGHWAY
P.C.C. & ST.L. RY.
XENIA
TWIN CR.
FARMERSVILLE
ELLERTON
ALEXANDERSVILLE
WEST CARROLLTON
84°
GRATIS
GERMANTOWN RETARDING BASIN
GERMANTOWN
MIAMISBURG
DAM
WEST ELKTON
MONTGOMERY CO.
PREBLE CO.
BUTLER CO.
CHAUTAUQUA
WARREN CO.
FRANKLIN
SPRINGBORO
DIXIE HIGHWAY
L. & F. EL. RY.
C.L. & N. R.R.
MIDDLETOWN
BLUEBALL
RED LION
P.C.C. & ST.L. RY.
C. & D. EL. RY.
B. & O. RY.
C.C.C. & ST.L. RY.
C.L. & N. R.R.
COKE OTTO
MIAMI RIVER
B. & O. R.R.
MONROE
DIXIE HIGHWAY
BUTLER CO.
WARREN CO.
DAYTON TO CINCINNATI 50 MILES
HAMILTON
JERICHO
40°

FIG. 2

improvement alone, and a system of many small retarding basins, were among the schemes that were found undesirable. After the present retarding basin—channel improvement plan was decided upon, much thought was given to the possibility of combining flood prevention and power development, but it was not found possible or practicable to make this combination in the Miami Valley.

The flood control plan provides for channel improvement through all the cities and towns affected by floods to the extent that is economically feasible, supplemented by retarding basins which will hold back the crest of the flood by restricting the flow through the dams and backing up the surplus water temporarily in the basins. There are no gates in the outlet structures through the dams. These structures are designed of such size that their combined discharge under maximum head (full basin) will not overtax the capacity of the improved river channels through the cities below. Provision is made to handle a flood 40 per cent greater than the 1913 flood. The studies and computations indicated that a flood 20 per cent greater than that of 1913 probably would be the greatest that might occur in the valley.

Channel improvement is provided at Piqua, Troy, Dayton, West Carrollton, Miamisburg, Franklin, Middletown and Hamilton. Dams forming retarding basins are located at Lockington on Loramie Creek; at Englewood on Stillwater River; at Taylorsville on the Miami; at Huffman on Mad River; and at Germantown on Twin Creek.

It was necessary to relocate about fifty miles of railroad lines in order to get them out of the way of the dams and retarding basins. New locations satisfactory to the railroad companies were made at the expense of the District, under the general direction of the railroad companies. This work cost about $5,000,000, exclusive of right of way and damages.

CONSTRUCTION OF PROJECT

All of the work, except the railroad relocations, was done by a construction organization built up and equipped by the District.

The quantities of materials involved were large; some of the major items are as follows:

Public service relocations

2,500,000 cubic yards excavation.
30,000 cubic yards concrete.
55 miles railroad track.

Flood prevention works

8,200,000 cubic yards embankment in dams.
2,550,000 cubic yards embankment in levees.
5,330,000 cubic yards excavation in river channels.
162,500 cubic yards concrete in outlet works at dams.
89,000 cubic yards concrete in walls and levee revetment.

Channel improvement. The combination of channel improvement and retarding basin control permitted the channel enlargement to be confined to moderate limits through most of the cities. The standard channel cross-section has a low-water section about 150 feet wide, with flat slopes or beaches on either side extending out to the toes of the levees. The low-water channel is located in the center where the river is straight and near the outside of the bends where the channel is curved. The side slopes of the levees are 2 to 1, and where necessary because of high velocities, the slopes are paved with concrete. Where conditions demanded, the levees are supplanted by retaining walls.

TABLE 1

Principal dimensions of dams

	GERMANTOWN DAM	ENGLEWOOD DAM	LOCKINGTON DAM	TAYLORSVILLE DAM	HUFFMAN DAM
Volume earthwork, cubic yards	800,000	3,600,000	970,000	1,130,000	1,350,000
Maximum height, feet	110	125	78	78	73
Length, feet	1,200	4,700	6,400	3,000	3,300
Maximum thickness at base, feet	665	785	415	415	380
Volume concrete work, cubic yards	17,400	26,500	32,000	48,000	37,500

Dragline excavators were used almost exclusively to handle the channel excavation and levee construction. They were also used for the excavation work at the dams. On the various jobs, twenty-one of these machines were used, varying in size from the small machine having a 30-foot boom and $\frac{3}{4}$-yard bucket to the large electric machines with 100-foot boom and 5-yard buckets.

In many places the dragline machines placed the material excavated from the channel directly into the levees. Sometimes two or three throws were necessary to get the material into the levees. At Dayton and Hamilton, where the excavation far exceeded the amount needed for levee construction, provision had to be made for wasting the excess material. This was accomplished at Hamilton by hauling the material out in trains of 12-yard dump cars to several spoil banks. At Dayton, on a large part of the work, it was not possible to lay tracks in the river bed, and the excess material was loaded on to scows which were towed to the spoil bank areas by a small steamboat.

At the cities where the principal improvement was levee construction, the work was done usually by dragline machines which excavated from adjacent borrow pits.

The dams. All of the five dams are of earth, built by the hydraulic fill method, and pierced by concrete conduits which carry the normal stream flow through the embankment.

The principal dimensions of the dams are given in table 1.

Construction camps were built at each dam site to take care of the required number of employees and their families, as there were no towns close enough to any of the dams to provide the necessary accommodation. These camps were made as comfortable and up-to-date as possible.

The first major construction job at each dam was building of the concrete outlet structure. These are of two types. At the higher dams,—Englewood and Germantown,—they consist of twin culverts or conduits passing entirely through the dam in the stream channel. The spillways at these dams are separate structures. At the three other dams, combination outlet and spillway structures were erected. All of these outlets were constructed on bed-rock foundations.

At the downstream end of each outlet structure a stilling pool was built for the purpose of dissipating the energy of the swiftly flowing water. This structure is so designed that the hydraulic jump or standing wave is formed within the limits of the concrete structure, and the floor and walls are made of sufficient thickness to withstand the action. The velocity is thus reduced, before it leaves the structure, to an extent that it will not erode the unlined channel below.

Construction of the dam embankments was handled as far as possible by hydraulic methods entirely. At most places the borrow pit material lay too low to be directly sluiced to the dams. The material was either sluiced from the borrow pits by hydraulic giants and then picked up by dredge pumps and conveyed to the dams through pipe lines, or was excavated by dragline machines, loaded on cars and hauled to the pumps near the toe of the dam and then pumped into place. Regardless of how the material was brought to the dredge pumps, the process from there on was practically the same at all of the dams. The hydraulic fill process automatically breaks up the borrow pit material into its component parts and distributes the material in the dam in such manner that the coarse material is left in the outer portion of the dam, forming stable outer slopes, and the fine material is concentrated in the center where it settles through a central pool or "core pool" to form an impervious core.

Progress and cost. Construction work began during the season of 1918. The intention was to push the work with all possible speed consistent with economy, because flood protection for the valley was of vital importance. All the larger jobs were started at once, and as far as practicable all work was carried on by two ten-hour shifts.

The rate of progress made varied with the equipment used. At Germantown, with one dragline machine in the borrow pit, and one dredge pump, an average month's work was 60,000 to 70,000 cubic yards, while the largest month's work was 91,500 cubic yards. At Taylorsville, with four giants in the borrow pits, and two dredge pumps, the highest monthly output was 107,000 cubic yards. At Englewood, with three dragline machines in the borrow pits, and two dredge pumps, the monthly record of hydraulic fill often reached 150,000 cubic yards, and during one month it amounted to 180,000 cubic yards.

By the middle of 1921 the work was in such shape that a repetition of the 1913 flood would cause only a limited amount of damage, and by the end of 1922 the work was ready to handle any flood that might occur.

The total cost of the project was about $30,000,000, of which approximately $24,500,000 was expended on construction and the balance for lands, damages, and other expenses. A considerable amount of the farm lands in the retarding basins is being sold, subject to flooding easements, and the land investment is thus being reduced.

MAINTENANCE ORGANIZATION

As soon as the construction of the works of the District was completed, a permanent maintenance organization was perfected and a definite program for the proper and necessary care of the works was mapped out. A headquarters office is maintained at Dayton in a building constructed for the purpose. The offices of the Chief Engineer and his assistants, the clerical and accounting force, the farm department and the tax department are located in this building. A central garage is also maintained at Dayton to care for the cars and trucks needed.

In each of the cities and towns where there are local protection works and at each of the five dams, resident caretakers are employed. These men, with help when necessary, patrol the levees and dams, remove debris, cut brush and weeds, look after the gates on the numerous sewers which extend through the levees, make daily readings of the river stage and rainfall and perform such other work as may be necessary.

Careful and continuous attention is given to all of the works and properties of the District. Any proposed structures, such as bridges and dams, or other construction, such as pipe lines or wire lines, which are contemplated by private or public interests and which in any way affect the works or property of the District, must be approved by the Chief Engineer. Special attention is given to the design of bridges over the streams to see that ample clearances are provided for maximum flows.

Measurements are made of the flow during high stages of the streams and of the flow through the dams in order to obtain actual data on the operation of the works.

OPERATION OF THE PROJECT

It was not long after the completion of the works of the District that they received their first real test, and the result was an excellent demonstration of the workings of the flood protection system.

On April 11,1922, a severe storm started which culminated on the 14th with very heavy showers. The rain poured in torrents all of that afternoon and then continued with lessened severity well into the night. This rain was general throughout the valley. An inch and a half fell in less than two hours in many places. The total rainfall for twenty-four hours, from midnight of the 13th to midnight of the 14th, was three and one half inches, and this fell on saturated ground.

Under the old conditions a flood stage of 18 feet in Dayton, the old danger mark, would have been exceeded, and a bad flood scare would have resulted. Actually, however, the river only reached a maximum stage of 9.6 feet in Dayton. About one-half of the reduction in gauge height was due to river channel improvements and the other half was due to the holding back of water behind the dams. All of the basins stored water, the maximum depth of backwater on the conduit floor at Germantown Dam being 40 feet, at Englewood Dam 37 feet, and lesser amounts at the other three dams.

Only 32 per cent of the channel capacity at Dayton was used, and only 4 per cent of the basin storage capacity was utilized. The storm had reached the stage where, had it continued, the rise in the river would have been relatively much slower, as the basins were holding back more and more of the runoff and were just really beginning to store any amount of water.

Everything worked out according to plan. The water was carried through the improved river channels in the cities smoothly and swiftly, the familiar turbulent appearance in former floods being entirely absent. At all of the dams the hydraulic jump worked just as expected and only a few hundred feet below each of the outlets the water was flowing smoothly. Practically no damage was done to property in the valley or to the works of the District.

There was intense interest by the public in the working of the system and it was necessary to place traffic men at the Englewood Dam to keep the crowds moving. The storms of April, 1922, were widespread and many communities suffered loss of life and property due to floods, but the citizens of the Miami Valley viewed their own situation with complacency. Less than one hundred telephone calls about the river stage were received at the Conservancy office as compared with nearly two thousand during the high water of 1920.

Since 1922 there have been several severe storms, and in each instance the flood control works functioned as planned and no damage resulted. On June 8, 1924, a near-cloudburst caused a rainfall of over 4½ inches in a few hours over the upper part of the Stillwater River watershed. The resulting flood of water caused a very rapid rise of the Stillwater River and its tributaries, but the Englewood Dam effectually checked the flow and the river at Dayton reached only the moderate stage of 13 feet. The maximum depth of the backwater at Englewood Dam was 52 feet, and the temporary lake covered an area of about 2300 acres.

From April, 1922, to January, 1927, there were four storms which would have caused considerable damage from flooding in the valley had the control works not been constructed. Excess water was stored behind the Germantown Dam on 35 occasions, and at Englewood 25 times, in the period referred to.

USE OF TWO WATER MAINS IN WIDE STREETS[1]

By Thomas F. Wolfe[2]

In the days, not long ago, when horse-drawn vehicles furnished the means of transportation and haulage, the narrow streets we find in the older sections of our big cities were ample for the traffic they were called upon to carry. The number of vehicles was few as compared to what we now have and the speed was limited. The introduction of the automobile changed these conditions. Streets that formerly took care of a few slow moving vehicles are now required to handle large numbers of fast moving automobiles. The net result is that where streets as narrow as 30 feet were once fairly common, we now find streets from 80 to 200 feet in width with roadways all the way from 40 to 80 feet. In addition to affecting the width of roadways, the automobile has influenced the design of the pavement. During the days of horse-drawn vehicles, wheel loads were necessarily limited by the capacity of the horse, whereas our modern motor trucks, with their immense loads and high speeds, have made it necessary to change the design of pavement with the result that our pavements are now not only wider but heavier and more expensive. This development of street design has had a marked effect on the distribution of water.

EFFECT OF WIDER STREETS ON DISTRIBUTION LINES

With the relatively narrow streets of former days, the logical way to distribute water to the separate lots was to lay a single main at or near the center of the street and to install services from this main to each lot on both sides of the street. In many cities these services were installed prior to paving the street, one service being laid for each separate parcel of ground. In other cities, the services were installed as needed with the result that the cost for each individual service was increased, because of the expense of opening and repairing a pavement. As street widths increase, a point is reached where it becomes more economical to use a two-main system for water distribution, one main being laid on each side of the street in place of a single main near the center. In the two-main system, the pipe on one side of the street is of sufficient size to provide for domestic consumption and to take care of the fire protection for both sides of the street, tapped, however, for services for one side only. The main on the other side is of smaller diameter, usually 4- or 6-inch, depending on the length of line between connections and, unless the street is unusually wide, should have no fire hydrants connected to it. In mentioning these sizes, it is presumed that the width of the street is not so great as to necessitate providing hydrants on both sides. If it should become necessary to have fire hydrants on both sides, the smaller of the two mains should be large enough to provide water for fire protection as well as for domestic supply. These two mains should be cross connected about every two blocks and properly valved. Each of these mains should be laid about 4 feet from the lot line or, if the sidewalks are laid immediately adjacent to the lot line, it might be advisable to lay these pipes about 1 foot from the outer edge of the walk.

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[1] Presented before the Buffalo Convention, June 9, 1926.

[2] Research Engineer, Cast Iron Pipe Publicity Bureau, Chicago, Ill.

With this type of distribution system, service pipes can be installed when buildings are being constructed. This makes it possible to install a service pipe of the proper size and at the proper location for each building and does away with the installation of service pipes for each separate parcel of ground prior to paving.

With the old scheme in vogue, many services were installed that were never used and many that were properly located were not large enough to take care of the size of building that was later constructed. The result is that many dead services now exist in our streets which represent an investment of a considerable amount of money and which have never been put to any use. The loss is not limited to money spent in laying these services, since we know it to be a fact that dead services are a prolific cause of trouble and it very often becomes necessary finally to cut them off at the main in order to keep down maintenance costs.

The use of the two-main system also eliminates the necessity of any service pipe crossing the street and puts the mains in parkways where the cost of digging up leaks is likely to be less than when pavements must be opened and later repaired. While the use of this system results in a greater mileage of main to be maintained, it cuts down the number and mileage of services to an even greater extent.

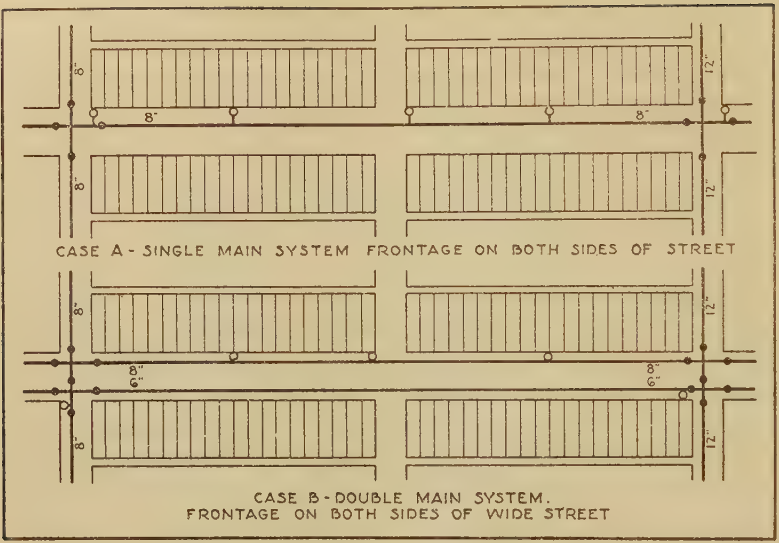
8"
12"
8"
8"
8"
12"
CASE A - SINGLE MAIN SYSTEM FRONTAGE ON BOTH SIDES OF STREET
8"
12"
8"
6"
8"
6"
8"
12"
CASE B - DOUBLE MAIN SYSTEM.
FRONTAGE ON BOTH SIDES OF WIDE STREET

FIG. 1. PLANS FOR SINGLE AND DOUBLE MAIN WATER SYSTEMS

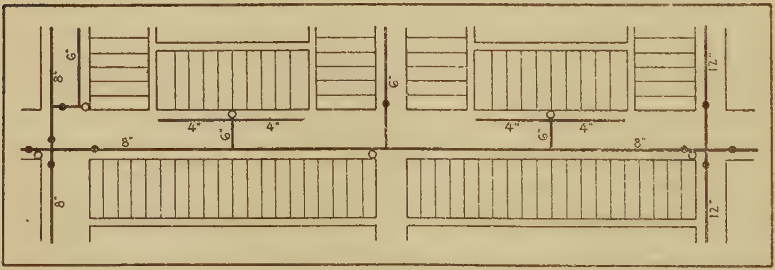

FIG. 2. PROPERTY FRONTING ON ONE ENTIRE SIDE AND PARTS OF OTHER SIDE

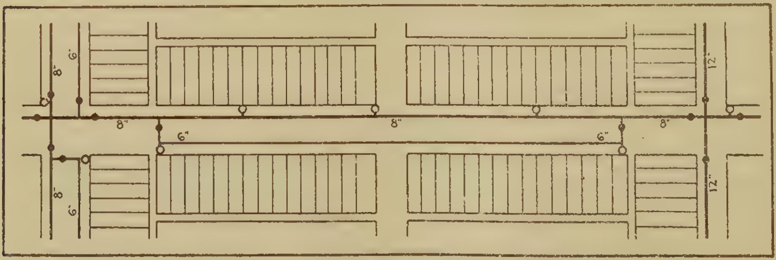

FIG. 3. PROPERTIES FRONTING PARTLY ON ONE BLOCK AND PARTLY ON ANOTHER

It also reduces the cost of maintenance by putting the mains inside of the curbs where any leaks that occur can be easily located without expensive openings and without traffic interference. The removal of water mains and services from the proximity of street car tracks, telephone cables and other possible carriers of return current, will cut down the amount of damage due to electrolysis.

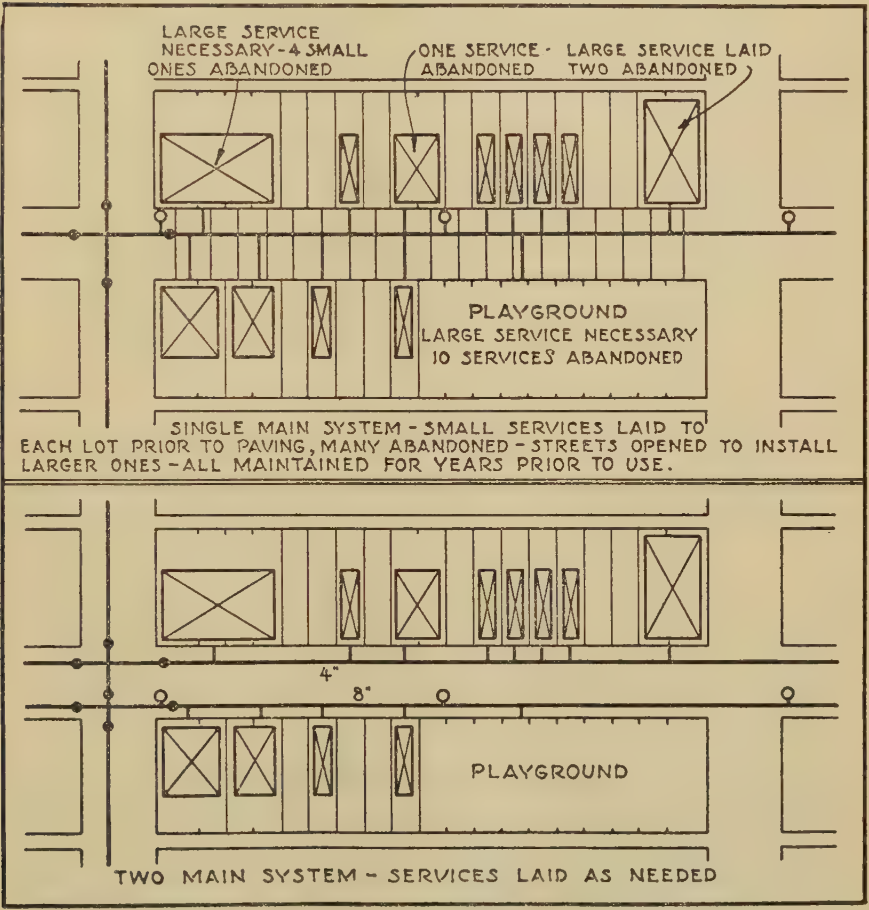
LARGE SERVICE NECESSARY - 4 SMALL ONES ABANDONED
ONE SERVICE - ABANDONED
LARGE SERVICE LAID TWO ABANDONED
PLAYGROUND
LARGE SERVICE NECESSARY
10 SERVICES ABANDONED
SINGLE MAIN SYSTEM - SMALL SERVICES LAID TO EACH LOT PRIOR TO PAVING, MANY ABANDONED - STREETS OPENED TO INSTALL LARGER ONES - ALL MAINTAINED FOR YEARS PRIOR TO USE.
4"
8"
PLAYGROUND
TWO MAIN SYSTEM - SERVICES LAID AS NEEDED

Fig. 4. Saving of Services in Double as Compared with Single Mains

There are cases where it is physically impossible to lay mains inside of the curb line, as, for instance, when the subsidewalk space is vaulted over and used by the property owner. In other cases rows of trees might interfere with the use of digging machines for installing the pipe when these machines might be used to advantage if the main were laid in the street. Even in these cases, the actual cost of the two main system should be estimated by the engineer in order to determine whether or not it would be economical.

In figures 1 to 5 several plans are indicated for providing services for property sub-divided along different lines. In figure 1, case A, we have a wide street with all the lots facing it and supplied by a single main. In figure 1, case B, we have the same lot layout, but supplied from two mains instead of one. In figure 2, the lots in the center of the block face the wide street while the lots at the end face the intersecting streets. In this case a single connection is laid across the street at about the center of the block and a small main laid each way from this connection to cover the frontage. The connection across the street could be made large enough to furnish water for one fire hydrant. In figure 3, the lots at one end of each block do not face the street in question. The second main is then laid to cover only the lots that actually face on the wide street. Additional details are shown in figures 4 and 5.

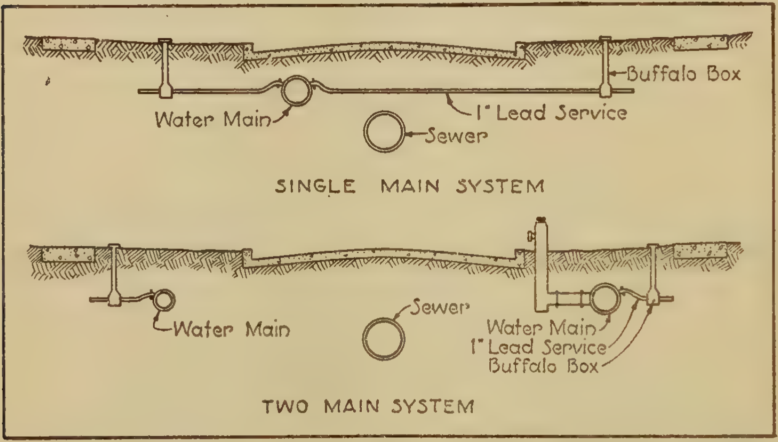

FIG. 5. COMPARISON OF METHODS FOR ARRANGING SINGLE AND DOUBLE MAINS

COSTS OF SINGLE COMPARED WITH DOUBLE MAINS IN WIDE STREETS

As an example of the relative cost of the two types of installation, we shall assume a street laid out so that each block consists of seventeen 30 foot lots and two 42 foot lots on each side of the street. A roadway of 42 feet is to be provided. The cost of the single main system for this street would be:

1320 feet, 8-inch main installed @ $2.32	$3062.40
2 feet, 8-inch valves installed including basin	170.00
76 feet, 1-inch lead services (2280 feet) including all labor and material @ $1.29 a foot	2941.20
Total	$6173.60

The cost of installing a two-main system to supply the same frontage would be:

1320 feet, 8-inch main installed @ $2.32	$3062.40
1320 feet, 4-inch main installed @ 1.35	1782.00
2 feet, 8-inch valves and valve boxes	100.00
2 feet, 4-inch valves and valve boxes	60.00
76 feet, 1-inch lead service (228 ft.) @ 1.29	294.12
Total	$5298.52

In the above estimate, it is assumed that the services in the single main system would extend to a point nine feet back of the curb and that in the two-main system each service would be 3 feet long. Under these conditions, the saving in original cost of the two-main system would be $875.08, assuming that all services were laid. In the case of the two-main system, certain services would be omitted, due to the fact that some buildings would occupy two or more lots and the real saving would consequently be even larger than indicated by the above figure.

As the width of the street increases, the relative saving increases and the costs are also affected by the cost of installing service pipes and by the width of the lots. The case is cited as an example and is not meant to cover all instances. The relative cost of the single and two-main system will be affected by local conditions. While the estimate given above may not apply to all cases, it at least points out the possibilities of economy in using the two-main system.

THE WATER SUPPLY PROBLEMS OF TENNESSEE[1]

By Howard R. Fullerton[2]

From topographical, mineral, agricultural and geographical standpoints, the State of Tennessee is naturally divided into three divisions. It follows that the water supply problems vary considerably over these three divisions and over the entire State. In eastern Tennessee with its mountains, rapidly running streams, and coal resources there has been an unprecedented industrial development. This has brought together large numbers of people unaccustomed to community life. This condition has increased very much the problem of obtaining safe water supplies for all residents in these fast growing and sometimes new communities. Central Tennessee has also undergone considerable growth and industrial expansion. The topography of the land is that of a plateau region, of limestone formation in the eastern part, grading to a lowland adjoining the Tennessee River on the West. The western grand division of the state lies between the Tennessee and Mississippi Rivers, and the majority of the territory is low, with sluggish and often overflowing streams. There is little of any outcropping of rock in this territory. The majority of the strata are intermittent layers of sand and clay for a depth of several hundred feet. Traces of iron and sulphur occur in some of the strata.

EAST TENNESSEE WATER PROBLEMS

In east Tennessee practically all of the water supplies are from springs or streams. In many instances the springs show some contamination, but are of sufficient clarity throughout the year that a potable water can be produced with chlorination only. Other spring supplies are sometimes turbid, and some are so abundantly supplied with sulphates and carbonates that softening is necessary as well as filtration. Two water supplies in eastern Tennessee of this latter type and class are at Greenville and Bristol.

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[1] Presented before the Kentucky-Tennessee Section meeting, January 20, 1927.

[2] Director, Division of Sanitary Engineering, State Department of Public Health, Nashville, Tenn.

After a town grows to the proportion of a city and the demands for water have increased accordingly, usually the water supply has to be considered from a volume standpoint first. The volume can, with few exceptions, be supplied only from a river. Several East Tennessee cities have now reached these proportions. Knoxville has secured its water for years from the Tennessee River. Johnson City has just had a survey completed for a new river supply and Kingsport will soon have to augment its present spring supply, most probably from the north branch of the Holston River.

MIDDLE TENNESSEE

This section in the eastern and central part is almost entirely underlaid with limestone formation with the bed rocks protruding at the surface or at best with only a few feet of earth on top.

In the western part near the Tennessee River, clay and sand strata are in evidence.

The peculiarity of underground waters in limestone, in that they will often flow for miles without receiving any natural filtration, tremendously increases the problem not only of securing an adequate water supply without excessive cost, but creates the additional problems of maintaining the supply safe for drinking and general domestic use after it is obtained. All of the well supplies in the middle section of the state are chlorinated where necessary and all of the spring supplies are so treated to make them safe. Nashville, Columbia and Shelbyville secure their supplies from rivers. They use coagulation, sedimentation, filtration and chlorination, with the exception of Nashville which does not filter. Bonds, however, have been voted and $1,500,000 are available to build the filters. Pumping equipment, both low and high lifts, has been bought and installed.

In the western part of middle Tennessee one of the water supplies is secured from a well, the others from springs.

WESTERN TENNESSEE

All of the municipal water supplies between the Tennessee River and Mississippi River are secured from wells. The city of Memphis has the largest municipal supply in the county secured exclusively

TABLE 1

Distribution of public water supplies in Tennessee, by population groups

GROUP	POPULATION OF TOWNS IN GROUPS HAVING PUBLIC WATER SUPPLIES	PER CENT OF TOTAL POPULATION IN GROUPS LIVING IN TOWNS HAVING PUBLIC WATER SUPPLY	NUMBER OF TOWNS HAVING PUBLIC WATER SUPPLIES	NUMBER OF TOWNS IN GROUP WITH NO WATER SUPPLY
20,000 and up	493,807	100	5	0
20,000–10,000	17,806	100	1	0
10,000–6,000	54,619	100	7	0
6,000–4,000	67,235	100	14	0
4,000–3,000	42,915	100	13	0
3,000–2,000	46,719	100	18	0
2,000–1,500	20,623	92.6	12	1
1,500–1,000	26,427	82.4	22	4
1,000–750	8,430	50.6	10	10
750–500	11,260	46.1	19	22
500–400	4,807	43.2	11	13

TABLE 2

Status of Tennessee water supplies

TYPE OF TREATMENT	NUMBER OF SUPPLIES
No treatment	77
Disinfection only	26
Coagulated, settled	1
Coagulated, settled, disinfected	2
Coagulated, settled, filtered	2
Coagulated, filtered, disinfected	1
Filtered, disinfected	2
Coagulated, filtered, settled, disinfected	24
Liquid chlorine	45
Hypochlorite of lime	8
Other disinfection (ultra violet ray)	1
Laboratory control:	
Chemical and bacteriological	10
Chemical only	1
Source:	
Wells	60
Springs	51
Surface	22

from wells. Much of the water in the western third of our state is impregnated to a more or less degree with sulphur and iron. The cities of Paris, Dyersburg, Ripley and Memphis are equipped for partial or entire removal of these unsatisfactory materials in the water. Covington is also experimenting with the water from one of its deep wells for carbon dioxide removal and is using aeration. Several other cities need treatment for removal of these undesirable materials from these waters.

THE PROBLEM OF DEVELOPING MUNICIPAL WATER SUPPLIES WHERE THEY ARE NEEDED

Table 1 shows the distribution of public water supplies for the cities by population groups.

The total population of state is 2,430,144, of which 32.6 per cent live in towns having public water supplies.

The status of water supplies already developed is shown in table 2. Of the 133 public water supplies, 79 are municipally, and 54 privately owned.

PROBLEMS OF OPERATION AND MAINTENANCE

As previously stated, there are 133 public water supplies in the state and they are distributed in cities ranging from 500 to 181,100 in population. These water supplies are of every sort and description and of almost every conceivable combination of processes.

The smaller cities and towns cannot in most instances pay for the desired class of water works operators because their revenues are too small. Some of the plants were constructed when water works practice was not developed to as high a degree as it is now. On new construction, sometimes a consulting engineer will contract to build a water plant when not so well qualified for the work as he might be.

The Tennessee State Department of Health early recognized that water supplies constitute one of the major sanitary engineering problems of any state. No other one single problem affects the health of so many people in a built-up community. The Department further realized that few, if any other problems, when properly solved will make for a higher standard of public health.

The larger plants in the state have competent supervision. In order to maintain the water supplies in a satisfactory condition each plant is visited twice a year by a sanitary engineer. He looks over the plant for needed repairs and extensions and instructs the superintendent in its scientific operation from mechanical, chemical and bacteriological standpoints. Outside of the four large cities only a few plants are doing bacteriological work, but this type of control is being recommended where it is believed to be possible.

Water works plants that use liquid chlorine have been furnished by the Division of Sanitary Engineering an inexpensive chemical testing outfit for testing for free chlorine. In this manner sufficient chlorine can be kept in the water to kill the bacteria, but not enough to be objectionable to taste. Although a bacteriological analysis may be made only once each month, the same amount of chlorine can be kept in the water as when the latter was examined and a safe water be reasonably assured for the rest of the month.

The water works are required, except in the four large cities, to submit water samples once each month to a state laboratory for analysis. The analyses are received by the Division of Sanitary Engineering and where results are poor the water works owners are communicated with at once and instruction given as to how to remedy the undesirable situation. A visit to the plant is also made when needed. Regulations require the submission of monthly operating charts and these are also reviewed and instruction given where improvements are needed.

It is necessary that the traveling public be protected against contaminated water on trains. The State Health Department coöperates with the United States Public Health Service in this matter and makes a survey of each water supply and bacteriological examinations of the water.

No discussion of water supply problem in Tennessee would be complete without some mention of stream pollution. With the rapid industrial development now taking place, stream pollution and its effect upon water supplies secured from these streams is receiving more and more attention by the State Department of Health through the Division of Sanitary Engineering. A sanitary engineer has been assigned to this work to make a complete study of it during the year 1927.

The problem is not only inter-state but also intra-state. We must not only protect the surface water supplies of our state against trade wastes and too heavy sewage contamination arising within our own boundaries, but protection must be provided against sources originating outside of the state.

We have already done a considerable amount of work on preventing stream pollution by domestic sewage, as all new municipal sewerage plans have been approved only after satisfactory plans for sewage disposal have been included in the design.

WATER SOFTENING AS AN ADJUNCT TO WATER PURIFICATION[1]

By Charles P. Hoover[2]

During the past five years municipalities having a raw water supply with a hardness in excess of 150 p.p.m. have been looking with favor toward water softening and as far as I know all municipalities, during this period, that have had occasion to build plants to improve their water supply, have in all cases, where the hardness exceeded 150 p.p.m., included softening.

Water works engineers have long recognized the economic results obtained by softening and many articles have been written calling attention to the losses occasioned by the use of hard water. The wastage of soap and other preparations for softening water has been emphasized as well as the extra expense of cisterns and double plumbing systems. The evil effects on fabrics, heat losses in hot water heaters and boilers and extra expense for operating steam boiler plants have also been calculated.

The consumers, of course, do not have a very definite idea as to the extent of the losses due to the use of hard water, but they fully appreciate the inconveniences with which they must contend on account of hard water. These inconveniences from hard water are perhaps noticed more by women than by men, because in the home, at least, they have occasion to use more of it.

The annoyances from hard water manifest themselves principally in the formation of scum in bath tubs, in laundry work, dish washing and the stopping up of water meters, heaters and pipes.

The added comforts of a softened water supply which the citizens of any community will experience by the change from hard to soft water cannot be fully appreciated until after it has been made.

The disadvantages of hard water and the economic losses from its use have long been recognized, nevertheless, until within the last five years, very few municipal water softening plants have been built and we may well ask why.

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[1] Presented before the Illinois Section meeting, January 27, 1927.

[2] Chemist in charge, Water Softening and Purification Works, Columbus, Ohio.

WHY SO FEW SOFTENING PLANTS WERE BUILT

There are several reasons why municipal water softening has not been looked upon with complete favor in the past. They are, as follows:

1. In the early days of the art of water softening, lime softened water was not stable because it was super-saturated with normal carbonates of calcium and magnesium and distribution systems carrying the water would become clogged with deposits of these carbonates and difficulty with the deposits were also encountered in meters and hot water systems. An extra amount of trouble was encountered with hot water pipes in hotels and public buildings stopping up on account of deposits formed in pipes, due to the fact that the water in these buildings is usually heated to a very high temperature.
2. Construction of water softening plants have always been regarded as very expensive because it was considered necessary to build large basins in which to store the water previous to filtration in order to allow long periods of time for chemical reactions to be completed.
3. Methods for handling, storing and applying large quantities of chemicals were crude.
4. The disposal of the large quantities of sludge formed by the softening reactions was a troublesome problem, and
5. The limited results that could be obtained in reduction of hardness on account of the increased solubility of substances causing alkalinity in water following the addition of soda ash.

Almost all of the difficulties and objectionable results obtained following water softening have now been entirely overcome and the others have been greatly improved.

RECARBONIZATION AND OTHER DEVELOPMENTS

Lime softened water may be cheaply and satisfactorily stabilized by recarbonizing it with carbon dioxide produced by burning coke, pulverized coal, oil or gas in a suitable furnace and forcing the gas, after being passed through a scrubber and drier, into the water. This gas is diffused into the water through small openings in a grid system and is applied to the water after it has passed through the settling basins and before it reaches the filters. The carbon dioxide converts the normal carbonates, which are only slightly soluble, to bi-carbonates, which are highly soluble, and will, therefore, not be easily precipitated from the water.

Chemicals used for softening can be thoroughly and satisfactorily mixed and agitated with the water in improved mechanical mixing devices which can be built at less cost than the old type baffled tanks, and the chemical reactions should be completed as far as possible in the mixing basin. If they are well completed in the mixing basin, the settling basin need not be much larger than that provided with ordinary filtration plants.

Large quantities of chemicals can be economically handled by unloading from the cars by means of power shovels or air suction devices and they may be cheaply elevated into bins from which they are subsequently fed into the water by gravity.

Dry feed machines for measuring the chemicals and others equipped with continuous lime slakers have been developed. Their introduction permits the elimination of chemical solution tanks with all the attendant difficulties, familiar to water works operators.

Apparatus has been developed which may be installed in the settling basins or clarifiers making it possible to remove the sludge produced from the water softening reactions continuously. Practically all of the municipal water softening plants built within the last five years have been provided with Dorr clarifiers for removing sludge continuously.

USE OF COAGULANTS IN SOFTENING

The limited results that could in the past be obtained in reduction of hardness seems to be largely due to the fact that the soda ash combines with the magnesium salts present in the water and forms complex basic carbonates or a complex double salt of sodium, magnesium, basic carbonates or perhaps colloidal precipitates of these salts. They may be represented by the following formulae:

$$\mathrm{Mg_4(OH)_2(CO_3)_3}$$
$$\mathrm{MgCO_3 \cdot NaHCO_3 \cdot 4H_2O}$$
$$\mathrm{MgCO_3 \cdot Na_2CO_3}$$

The basic carbonates are formed even when lime alone is used as a softening reagent, if the water being treated contains magnesium carbonate, but we know that water high in non-carbonate hardness is more difficult to soften than water with an equivalent amount of hardness, but low in non-carbonate hardness, because non-carbonate hardness requires soda ash for its removal and large amounts of soda ash are conducive to the formation of these basic carbonates.

It has, of course, long been recognized that the product of the reaction between lime and bi-carbonates in the water is not an entirely insoluble compound. About two grains per gallon (34 parts per million) of the calcium and magnesium compounds remain in the solution; so that by the lime-soda ash treatment, it is theoretically, not possible to reduce the hardness to less than two grains per gallon. If it were possible to reduce the hardness of the water treated to two grains per gallon by adding the theoretical amounts of lime and soda ash required to combine with the carbonate and non-carbonate hardness salts, the limitation of being able to obtain a two-grain water would not be especially objectionable, for two grain hardness water is satisfactory for almost all purposes. Unfortunately, however, in past practice it has been impossible to reduce the hardness of a hard magnesium water by the lime-soda ash process to two grains per gallon unless the water being softened was heated or unless excess lime and soda ash were added. Overtreated cold, softened water usually contains from two to four grains of sodium hydroxide because, as has already been stated, to reduce the hardness of water to two grains per gallon, more chemical than is theoretically required, must be used. That is, excess lime must be added in order to precipitate completely the bi-carbonate of calcium and magnesium and sufficient soda ash added to neutralize the non-carbonate hardness, plus an additional amount to convert the excess CaOH to NaOH, as shown by the formula, $Ca(OH)_2 + Na_2CO_3 = 2NaOH + CaCO_3$. Excess treatment increases the cost to between five and six dollars per million gallons and if practiced at the Columbus plant, where it is the policy to leave approximately 30 to 35 parts per million of non-carbonate hardness in the water, the cost of excess treatment would be increased about $10.00 per million gallons. The treatment also introduces into the treated water salts that are conducive to foaming when the water is used for boiler feed purposes.

Results of experimental tests conducted at the Columbus plant indicate that by the addition of a coagulant such as sulfate of alumina or sodium aluminate (3 to 5 grains) along with the lime and soda ash, the hard water from the Scioto river may be satisfactorily softened to a hardness of between 35 and 50 parts per million without resorting to excess treatment with lime and soda ash, whereas, without the use of coagulant the limit seems to be somewhere between 90 and 100 parts per million.

It has already been explained that the addition of soda ash to remove the non-carbonate hardness is largely responsible for the formation of soluble hardness salts. Now we know that it is not necessary and in many cases not advisable to use soda ash to remove permanent or non-carbonate hardness from water in communities where salt may be obtained at a fair cost, because it is cheaper to remove non-carbonate hardness by means of the zeolite process than by soda ash.

ZEOLITE PROCESS

Zeolite softening material may be a synthetic product or a natural one. The synthetic product is in composition a hydrated sodium aluminium silicate and is being manufactured by several reliable companies. Natural or so called green sand zeolite is found in large quantities in the state of New Jersey. Green sand has the appearance of ordinary filter sand except that it has a green color when dry. It can be graded so as to have an effective size of around 0.4 mm. and a uniformity coefficient of 1.60 which is standard grading for filter sand. It has, like the artificial zeolites, the property of being able to exchange its base, sodium, for the calcium and magnesium in the water that is brought into contact with it. Hard water may be softened to zero hardness by simply filtering it through a bed of the zeolite material. The calcium and magnesium salts in the water are not precipitated as in the lime-soda ash method but are replaced or exchanged, as has already been indicated, by the sodium from the zeolite. In other words, calcium and magnesium are the mineral salts which in solution in water cause it to be hard. When they are replaced by sodium, the water is soft.

When the zeolite has exchanged its sodium for calcium and magnesium it becomes inert and must be regenerated and this is done by passing a solution of common salt (sodium chloride) through the material. Thus the sodium from the sodium chloride washes out or replaces the calcium and magnesium taken from the water and reconverts the zeolite back to its original condition.

Salt Costs for Removing Hardness

One cubic foot of green sand will remove 3000 grains of hardness before being exhausted and according to the results obtained at McKees Rock, Pa., 0.315 pound of salt was required for each 1000 grains of hardness removed. Salt at McKees Rock costs $6.75 per ton delivered. Based on McKees Rock's figures the salt cost of removing 1 part per million hardness per million gallons equals $0.062. During the year 1925 the average cost of lime at Columbus, Ohio, for removing 1 part of carbonate hardness per million gallons was $0.057, and the average cost of soda ash for removing 1 part per million permanent or non-carbonate hardness per million gallons was $0.125. These figures show that the cost for salt or softening water through zeolite is only about one half the cost of soda ash for removing non-carbonate hardness. In addition to the salt cost, an extra allowance should be made for wash water when using the zeolite method as about 10 per cent wash water is wasted in this process.

Advantages of Zeolite Process

The zeolite process offers several advantages over the soda-ash-treatment in addition to cost. First, the complications of reactions, referred to in an earlier paragraph of this paper and explained in detail in the 1925 report of the Division of Water, Columbus, Ohio, are eliminated and, second, water of any degree of hardness may be obtained and this is not possible to accomplish with the lime-soda-ash process.

At the Columbus plant it is now planned to take the filter sand out of one of our mechanical filters and replace it with zeolite sand. The operation of this one filter will be regarded as an experiment and the results obtained from its operation will probably determine whether or not more of the filters will be converted into zeolite softeners.

OPERATION OF LIME-ZEOLITE SOFTENING PLANT

The process of operating a lime zeolite softening plant would be about as follows: The water pumped into the plant would be first treated with sufficient lime to reduce the temporary or carbonate hardness to the lowest possible figure. Lime and alum would be mixed with the water in the mixing tanks and then passed through the settling basins just the same as it does now to remove the precipitated carbonates. At the end of the settling basins, the lime softened water would be carbonated with carbon dioxide gas in order to convert the normal carbonates to bi-carbonates, thus preventing the deposition of normal carbonates on the zeolite sand and to prevent the formation of normal sodium carbonate in the softened water. The presence of sodium bicarbonate in the zeolite softened water makes it possible to mix it with water containing non-carbonate hardness and not get a precipitation or after reaction. From the settling basins the water would flow to the filters and, if desirable, to reduce it to zero hardness, all the water would be passed through zeolite filters. If it is desirable to leave some residual hardness in the water, then, of course, it would only be necessary to filter a portion of the water through zeolite filters.

At the Columbus plant it is believed that it will be possible to reduce the hardness of the water to 160 parts per million with the lime treatment alone and that in order to produce a softened water with a total hardness of say 80 parts per million, it will be necessary to filter only half of it through zeolite filters, reducing the hardness of one-half portion to zero, and then mixing it with the other half portion having a hardness of 160 parts per million giving a resultant product with a hardness of 80 parts per million. No after reactions are expected, because the residual sodium salts in the zeolite softened water are present as bi-carbonates.

DIFFERENCES BETWEEN WATER FILTRATION AND WATER SOFTENING

The principal differences between a water filtration plant and a water softening plant are: 1. A water softening plant must have additional facilities for storage of chemicals and their application to the water. 2. More adequate mixing devices for agitation of the chemicals with the water are required. 3. A mechanism for continuously removing the sludge. 4. A carbonization plant.

With the addition of these facilities almost any water purification plant may be converted into a softening plant and the extra cost of including these facilities at the time of building a plant is not great when the advantages to be obtained by softening a hard water supply are considered.

ADDED ADVANTAGES OF SOFTENING

In addition to the added comforts and benefits which the citizens of any community will experience by the change from hard to soft water, the softening process increases the efficiency of the filtration plant operation because better coagulation is effected, more organic matter and color are removed, iron, if present, is eliminated, the treated water is non-corrosive, and intestinal and pathogenic bacteria are killed.

At the Columbus plant the bulk of the precipitate formed by the softening reactions is about 20 times as great as could be obtained by ordinary coagulation processes. The efficiency of this large volume of precipitate, as a coagulant, is greatly increased, if the water treated contains magnesium compounds, because the lime reacts with them to form magnesium hydroxide, a bulky gelatinous precipitate which coagulates the suspended clay particles or mud as readily as the precipitates formed by sulphates of alumina or iron. If the quantity of magnesium salts is small in the water being softened, then of course a small quantity of coagulant may be added, along with the softening chemicals, in order to make the precipitate formed more gelatinous and thus rendering it more efficient as a coagulant.

A properly lime softened water should have, at the time it is ready to leave the settling basins, a bright greenish look and a turbidity not to exceed 1 or 2 parts per million. One should be able to see an object immersed in it to a depth of at least 5 feet. Such a water in addition to being low in turbidity will be low in color and organic matter and practically free from intestinal and pathogenic bacteria. The load on the filters will be greatly lessened and filter costs reduced because filtration rates may be increased. The load applied to the filters should be so light that filter runs should be lengthened to at least 48 hours between washings. At the Columbus plant filters have on special occasions been run continuously for periods of six days between washings.

Coagulation, filtration and chlorination can be used in almost all instances to produce a water that is clear and safe for drinking purposes, but sometimes the amount of chlorine required to make sure that the water is safe bacterially is so high that the treated water may not be palatable on account of disagreeable tastes and odors.

It is well known that, if water contains a slight amount of phenol or large amounts of organic matter, the addition of chlorine will intensify any tastes or odors that may be present in the water.

EXCESS LIME FOR DISINFECTION

Dr. A. C. Houston, Chemist of the Metropolitan Water Board, London, England, first proposed the excess lime method of sterilizing water. His results were confirmed by Hoover and Scott at Columbus, Ohio,[3] and have since been confirmed at a number of other water softening plants.

Scott and McClure, experimenting with Ohio water supplies at Youngstown, Defiance, Bellaire, Cincinnati, Niles and Sandusky, found that in those plants using enough lime to produce a water with a pH value greater than 9.5, B. coli were not found in 50 cc. portions out of a total of 25 samples tested. At those plants where only enough lime was added to assist in coagulation and the pH value was less than 9.5, B. coli were present, with one exception, in 22 samples, in 50 cc. portions and usually in 10 cc. portions. They conclude that bacteria of the colon typhoid group are destroyed in media of low hydrogen-ion concentration, the limiting value being 9.5. A natural water treated with the theoretical amount of lime required to soften it will have a pH value of approximately 9.5.

At the Columbus plant it is customary to omit the chlorine treatment entirely during flood periods when the organic matter is high and the water has a tendency to have an unpleasant taste or odor. At the time when chlorine treatment is cut out, excess lime treatment is resorted to, about 20 p.p.m. caustic alkalinity being carried in the filtered water. This amount of caustic alkalinity is not noticeable to the consumer.

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[3] National Lime Association Bulletin. Water Softening.

TYPHOID FEVER IN THE LARGE CITIES OF THE UNITED STATES IN 1926[1]

The Journal presents its fifteenth annual survey of typhoid fever mortality in the seventy-eight cities of the United States that had more than 100,000 population in 1926.[2] As in the fourteenth report, the cities have been grouped according to the recognized divisions of the U. S. Census Bureau. One city (Jacksonville) appears for the first time in our tables.[3]

The cities of the New England group (table 1) make a remarkable showing, and one that would be creditable to any similar population group anywhere in the world. No less than seven of the twelve New England cities report typhoid death rates of less than 1 per hundred thousand of population. The total rate for the group (1.51) is the lowest for any geographic division in the United States (table 11). Two New England cities (New Bedford and Lowell) have had rates under 1 per hundred thousand of population for two years in succession, the average for the two years in Lowell being under 0.5 per hundred thousand, or less than one-twentieth of the average for the quinquennium 1911–1915. Cambridge almost alone among New England cities seems to have had an undue number of deaths from typhoid in 1926, its rate (4.9) being more than three times the New England average. It will be remembered that this city also had a high typhoid year in 1921, with a rate of 10.8. The occasionally excessive typhoid in Cambridge in recent years is all the more noteworthy since, for the sixteen years 1906–1920, this city had easily the best typhoid record in New England.

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[1] Reprinted from the Journal of the American Medical Association, 88: 15 April 9, 1927, p. 1148.

[2] The preceding articles were published in Jour. Amer. Med. Assoc., May 31, 1913, p. 1702; May 9, 1914, p. 1473; April 15, 1915, p. 1322; April 22, 1916, p. 1305; March 17, 1917, p. 845; March 16, 1918, p. 777; April 5, 1919, p. 997; March 6, 1920, p. 672; March 26, 1921, p. 860; March 25, 1922, p. 890; March 10, 1923, p. 691; Feb. 2, 1924, p. 389; March 14, 1925, p. 813, and March 27, 1926, p. 948.

[3] The deaths from typhoid in each city are those reported to us by the respective health departments. The rates have been calculated on the basis of the midyear 1926 population as estimated by the U. S. Bureau of the Census. In the nine instances in which such estimates were not available, the midyear population figures were furnished by the health departments of the respective cities.

In the Middle Atlantic states (table 2) three cities (Albany, Utica, Yonkers) achieve the proud distinction of having had not a single typhoid death in 1926. The other cities of the group for the most part make an admirable showing. Attention may be called especially to the remarkable records of Philadelphia and Pittsburgh in 1926, as contrasted with the typhoid rates from which these cities suffered in the period 1906–1910. Those who are inclined to minimize or to forget the importance of water-borne typhoid may well ponder these figures. Philadelphia, a city with distinctly less favorable climatic conditions than New York and presumably with a high legacy of typhoid carriers from the long period when typhoid ravaged the city, now rivals New York in its low typhoid rate. In Pittsburg the average typhoid mortality in the years 1906–1910 was nearly twenty-

TABLE 1

Death rates of cities in New England States from typhoid per hundred thousand population

	1926	1925	1921–1925	1916–1920	1911–1915	1906–1910
Worcester	0.5	2.1	2.3	3.5	5.0	11.8
Bridgeport	0.6*	2.8†	2.2	4.8	5.0	10.3
New Bedford	0.7‡	0.8	1.7	6.0	15.0	16.1
Providence	0.7	3.4	1.8	3.8	8.7	21.5
Springfield, Mass	0.7	1.4	2.0	4.4	17.6	
Fall River	0.8	1.5	2.3	8.5	13.4	13.5
Lowell	0.9§	0.0	2.4	5.2	10.2	13.9
Hartford	1.2	1.9	2.5	6.0	15.0	19.0
Boston	1.8	3.5	2.2	2.5	9.0	16.0
New Haven	2.2	1.7	4.4	6.8	18.2	30.8
Lynn	3.8	1.0	1.6	3.9	7.2	14.1
Cambridge	4.9	1.7	4.3	2.5	4.0	9.8

* Rate calculated on population figures furnished by the health department: 170,717.

† Rate calculated on figures for population in 1922.

‡ Rate calculated on population figures furnished by the health department: 135,132.

§ Rate calculated on population figures furnished by the health department: 112,759.

five times as great as the typhoid rate for 1926. The typhoid records in these two great cities constitute an outstanding demonstration of the efficacy of water purification.

Two of the Middle Atlantic cities (Rochester and Scranton) are somewhat out of line with the rest of the group in that they not only had in 1926 a considerable higher typhoid mortality than in 1925, but also a higher rate than for the two preceding five year periods. Camden shows a decline in 1926 as compared with 1925, which is an encouraging indication. An explanation seems to be warranted about the Buffalo rate which, as reckoned according to the ordinary methods, gives a somewhat false impression. It is officially reported that ten of the twenty-seven deaths in that city in 1926 were from cases contracted in a neighboring community which suffered from a severe outbreak. Making allowance for this unusual occurrence, the record of typhoid infection in the city of Buffalo itself would seem to have been excellent. The rate for the whole geographic division (table 11) in 1926 (2.12) was much lower than in 1925 (3.01).

TABLE 2

Death rates of cities in Middle Atlantic States from typhoid per hundred thousand population

	1926	1925	1921–1925	1916–1920	1911–1915	1906–1910
Albany	0.0	5.9	5.6	8.0	18.6	17.4
Utica	0.0	3.9				
Yonkers	0.0	1.8	1.7	4.8	5.0	10.3
Syracuse	1.1	2.2	2.3	7.7	12.3	15.6
Paterson	1.4	2.1	3.3	4.1	9.1	19.3
Newark, N. J.	1.5	0.9	2.3	3.3	6.8	14.6
Jersey City	1.9	4.1	2.7	4.5	7.2	12.6
New York	1.9	3.3*	2.6	3.2	8.0	13.5
Philadelphia	1.9	2.3	2.2	4.9	11.2	41.7
Trenton	2.2	3.8	8.2	8.6	22.3	
Reading, Pa	2.6	0.9	6.0	10.0	31.9	42.0
Pittsburgh	2.7	3.2	3.9	7.7	15.9	65.0
Rochester	4.0	1.9	2.1	2.9	9.6	12.8
Scranton	4.2	0.0	2.4	3.8	9.3	31.5
Camden	4.6	7.0	5.9	4.9	4.5	
Buffalo	5.0	4.5	3.9	8.1	15.4	22.8

* Rate calculated on figures for population in 1924, with same annual increment added as in 1922–1923, 1923–1924.

The cities of the South Atlantic states (table 3) show a slight improvement, the rate for the geographic group dropping from 5.71 in 1925 to 5.38 in 1926 (table 11). The rate in the national capital (Washington, D. C.) is relatively very low (2.5) and marks a gratifying decrease over the previous low record (3.7 in 1919). Richmond also makes a fine showing. Atlanta, almost alone in this group, has shown little change for the better in the last ten years.

The cities in the East North Central states (table 4) again make an excellent record. One city (Youngstown) does not have a single typhoid death to its discredit. Chicago establishes a new low record, the rate (0.8) being the lowest reported in 1926 for any American city with over 500,000 population. Chicago is one of the cities in which typhoid is carefully watched, a full analysis of the cases being published annually. It is stated in the annual report that the ratio of out-of-town infections to the total cases is about 1:3, and that in more than half of all cases reported the apparent modes of infection have been traced. The Chicago analysis states that in 1926 about 75 per cent of the typhoid cases were treated at hospitals. It is evident that with the increasing rarity of this disease, hospitalization is becoming more practicable, a circumstance that is highly favorable since it affords proper opportunities for control. Two cities in this

TABLE 3

Death rates of cities in South Atlantic States from typhoid per hundred thousand population

	1926	1925	1921–1925	1916–1920	1911–1915	1906–1910
Norfolk	1.7	1.5*				
Wilmington	2.4	3.3	4.7			
Washington	2.5	5.0	5.4	9.5	17.2	36.7
Richmond	2.6	5.4	5.7	9.7	15.7	34.0
Baltimore	4.7	3.6	4.0	11.8	23.7	35.1
Jacksonville	8.8					
Atlanta	17.2†	18.4‡	14.5	14.2	31.4	58.4

* Rate calculated on figures for population in 1924, with same annual increment added as in 1922–1923 and 1923–1924.

† Rate calculated on population figures furnished by the health department: 266,488.

‡ Rate calculated on population figures furnished by the health department: 250,000.

group (Toledo and Indianapolis) continue to have rates considerably higher than the average. Columbus and Grand Rapids, which also had high rates in the period 1906–1920, have made considerably better records than Toledo and Indianapolis in recent years.

The four cities in the East South Central states (table 5) appear to be in the worst typhoid belt in the United States. For the second successive year the total rate for this group (table 11) has been higher than that of any other geographic division. Birmingham and Memphis report lower rates in 1926 than in 1925, the figure for Birmingham being 8.5, which is especially encouraging. Nashville, on the other hand, appears to have suffered early in the summer from an old-fashioned typhoid epidemic, which carried its rate for the year to the highest point reached in any American city (35.0). The highest rate in 1925 was 28.6 (Memphis); and in 1924 the highest was 41.2 (Memphis).

TABLE 4

Death rates of cities in East North Central States from typhoid per hundred thousand population

	1926	1925	1921–1925	1916–1920	1911–1915	1906–1910
Youngstown	0.0	2.5	7.2			
Flint	0.7	1.5				
Chicago	0.8	1.5	1.4	2.4	8.2	15.8
Grand Rapids	1.3	1.3	1.9	9.1	25.5	29.7
Cleveland	1.4	1.5	2.0	4.0	10.0	15.7
Akron	1.5*	1.9†	2.4			
Columbus	1.7	4.3	3.5	7.1	15.8	40.0
Milwaukee	1.7	1.4	1.6	6.5	13.6	27.0
Detroit	2.2	2.7	4.1	8.1	15.4	22.8
Dayton	2.3	1.7	3.3	9.3	14.8	22.5
Cincinnati	2.7	4.2	3.2	3.4	7.8	30.1
Canton	3.6	0.9				
Toledo	4.7	6.3	5.8	10.6	31.4	37.5
Indianapolis	5.4	3.6	4.6	10.3	20.5	30.4

* Rate calculated on population figures furnished by the health department: 200,000.

† Rate calculated on figures for population in 1924.

The cities of the West North Central states (table 6) pursue the even tenor of their way, only one city (Kansas City, Mo.) having a higher rate in 1926 than in 1925. Rates in this group show for the

TABLE 5

Death rates of cities in East South Central States from typhoid per hundred thousand population

	1926	1925	1921–1925	1916–1920	1911–1915	1906–1910
Louisville	6.7*	5.8	4.9	9.7	19.7	52.7
Birmingham	8.5	9.2	10.8	31.5		
Memphis	19.2	28.6	20.3	27.7	42.5	35.3
Nashville	35.0	19.8	17.8	20.7	40.2	61.2

* Data for year September 1, 1925 to August 31, 1926.

TABLE 6

Death rates of cities in West North Central States from typhoid per hundred thousand population

	1926	1925	1921–1925	1916–1920	1911–1915	1906–1910
Duluth	0.8	0.9				
St. Paul	1.2	2.8	3.4	3.1	9.2	12.8
Minneapolis	1.4	3.3	1.9	5.0	10.6	32.1
Omaha	1.8	1.9	3.3	5.7	14.9	40.7
St. Louis	2.3	3.9	3.9	6.5	12.1	14.7
Des Moines	2.7	4.7*	2.2			
Kansas City, Mo.	3.5	1.9	5.7	10.6	16.2	35.6
Kansas City, Kan.	4.3	7.7	5.0	9.4		

* Rate calculated on figures for population in 1924, with the same annual increment added as in 1922–1923 and 1923–1924.

TABLE 7

Death rates of cities in West South Central States from typhoid per hundred thousand population

	1926	1925	1921–1925	1916–1920	1911–1915	1906–1910
Houston	6.0*	5.5	7.6			
San Antonio	7.8	8.6	9.3	23.3	29.5	
Dallas	8.9	17.5	11.2	17.2		
El Paso	9.2	3.8	10.8	30.7	42.8	
Fort Worth	10.7	5.2	6.1			
Tulsa	14.3	20.9				
New Orleans	18.6	19.8	11.6	17.5	20.9	35.6

* Rate calculated on population figures furnished by the health department: 250,000.

most part little fluctuation and for the past ten years have been rarely marked by any epidemic prevalence. Duluth, which started out in 1925 with 0.9, repeats this excellent record in 1926.

The cities of the Southwest (table 7), on the other hand, show considerable annual variation. Dallas and Tulsa, which were high in 1925, record substantial reductions in 1926, while El Paso and Fort Worth report considerable increases. The New Orleans typhoid rate appears to be ranging somewhat higher than in the years 1916–1924.

TABLE 8

Death rates of cities in Mountain and Pacific States from typhoid per hundred thousand population

	1926	1925	1921–1925	1916–1920	1911–1915	1906–1910
Salt Lake City	0.7	6.9	6.0	9.3	13.2	
Oakland	0.8	1.2	2.0	3.8	8.7	21.5
San Diego	0.9	0.9				
Los Angeles	1.1*	1.3*	3.0	3.6	10.7	19.0
Seattle	2.3†	2.5‡	2.6	2.9	5.7	25.2
Portland, Ore	2.5§	2.1	3.5	4.5	10.8	23.2
San Francisco	2.5	2.2	2.8	4.6	13.6	27.3
Denver	3.5	5.0	5.1	5.8	12.0	37.5
Tacoma	3.8	1.9	3.7	2.9	10.4	19.0
Spokane	6.5	1.8	4.4	4.9	17.1	50.3

* Rate calculated on population figures furnished by the health department: 1,200,000.

† Rate calculated on population figures furnished by the health department: 345,000.

‡ Rate calculated on figures for population in 1924, with same annual increment added as in 1922–1923 and 1923–1924.

§ Rate calculated on population figures furnished by the health department: 314,795.

The cities in the Mountain and Pacific states (table 8) show less proportionate typhoid reduction than those in the other geographic divisions, Portland (Oregon), San Francisco, Tacoma and Spokane all having higher rates in 1926 than in 1925. Spokane, which was on the Honor Roll in 1925 with a rate of 1.8, brings up at the foot of this division in 1926. Oakland, however, which led this list in the quinquennium 1921–1925, again stands very high for the year 1926. San Diego repeats its excellent figure of last year (0.9), and Salt Lake City makes the fine new low record of 0.7.

TABLE 9

Death rates from typhoid in 1926

Honor Roll (from 0.0 to 2.0 Deaths per Hundred Thousand)			
Albany	0.0	Syracuse	1.1
Utica	0.0	Hartford	1.2
Yonkers	0.0	St. Paul	1.2
Youngstown	0.0	Grand Rapids	1.3
Worcester	0.5	Cleveland	1.4
Bridgeport	0.6	Minneapolis	1.4
Flint	0.7	Paterson	1.4
New Bedford	0.7	Akron	1.5
Providence	0.7	Newark	1.5
Salt Lake City	0.7	Columbus	1.7
Springfield, Mass	0.7	Milwaukee	1.7
Chicago	0.8	Norfolk	1.7
Duluth	0.8	Boston	1.8
Fall River	0.8	Omaha	1.8
Oakland	0.8	Jersey City	1.9
Lowell	0.9	New York	1.9
San Diego	0.9	Philadelphia	1.9
Los Angeles	1.1		
First Rank (from 2.0 to 5.0)			
Detroit	2.2	Pittsburgh	2.7
New Haven	2.2	Denver	3.5
Trenton	2.2	Kansas City, Mo	3.5
Dayton	2.3	Canton	3.6
St. Louis	2.3	Lynn	3.8
Seattle	2.3	Tacoma	3.8
Wilmington	2.4	Rochester	4.1
Portland, Ore	2.5	Scranton	4.2
San Francisco	2.5	Kansas City, Kan	4.3
Washington	2.5	Camden	4.6
Reading, Pa	2.6	Baltimore	4.7
Richmond	2.6	Toledo	4.7
Cincinnati	2.7	Cambridge	4.9
Des Moines	2.7		
Second Rank (from 5.0 to 10.0)			
Buffalo	5.0	San Antonio	7.8
Indianapolis	5.4	Birmingham	8.5
Houston	6.0	Jacksonville	8.8
Spokane	6.5	Dallas	8.9
Louisville	6.7	El Paso	9.2
Third Rank (over 10.0)			
Fort Worth	10.7	New Orleans	18.6
Tulsa	14.3	Memphis	19.2
Atlanta	17.2	Nashville	35.0

For the first time since these summaries were undertaken, as many as four cities have got through the year without a death from typhoid, and in more than a dozen others the typhoid rate was less than 1.0. The Honor Roll (cities with from 0.0 to 2.0 typhoid deaths per hundred thousand of population) this year numbers thirty-five, as against thirty last year and eighteen in 1924 (table 9). Six cities have been compelled to take third rank (rates above 10), the same number as in 1925. Nashville, Memphis, New Orleans, Atlanta and Tulsa also occupied positions in the third rank last year. Dallas has risen from third to second rank, but Fort Worth has dropped from second into the lowest class, while El Paso, in the first rank in 1925, just escapes being in the third rank in 1926.

TABLE 10

*Total typhoid death rate for fifty-nine cities, 1910-1926**

	POPULATION	TYPHOID DEATHS	TYPHOID DEATH RATE PER 100,000
1910	21,125,340	4,143	19.61
1911	21,679,886	3,416	15.71
1912	22,234,865	2,800	12.59
1913	22,788,282	2,923	12.82
1914	23,342,199	2,443	10.46
1915	23,896,616	2,094	8.76
1916	24,368,470	1,874	7.69
1917	24,908,055	1,684	6.76
1918	25,142,605	1,583	6.30
1919	25,702,711	1,006	3.91
1920	26,340,793	934	3.54
1921	26,749,616	992	3.71
1922	27,133,857	862	3.18
1923	27,566,727	866	3.14
1924	28,174,489	870	3.09
1925	28,882,031	993	3.43
1926	29,620,891	822	2.77

* The following nineteen cities are omitted from this summary because data for the full period are not available: Akron, Birmingham, Camden, Canton, Dallas, Des Moines, Duluth, Flint, Fort Worth, Houston, Jacksonville, Kansas City (Kan.), Norfolk, San Diego, Springfield, Tulsa, Utica, Wilmington, Youngstown.

The total average typhoid death rate for fifty-nine cities (table 10) is the lowest ever reported (2.77). This is in marked contrast to the rate in 1925, which showed a considerable increase over the three preceding years. Just as emphatically as 1925 was a "bad" typhoid year, so 1926 was a "good" typhoid year. In 1926 every geographic division except the East South Central states showed a decrease (table 11).

The fact that the large cities in the United States had an actual diminution of 170 deaths from typhoid in 1926, as compared with 1925 (table 10), even although an estimated population increase of nearly a million occurred, should give great satisfaction to the municipal health officers, to whom the credit for this achievement is mainly due.

TABLE 11

*Total typhoid death rate according to geographic divisions—seventy-eight cities in 1926, seventy-seven cities in 1925**

	POPULATION, 1926	1926		1925	
		Typhoid deaths	Typhoid death rate per 100,000	Typhoid deaths	Typhoid death rate per 100,000†
New England states	2,521,608	38	1.51	58	2.37
Middle Atlantic states	11,399,000	241	2.12	346	3.01
South Atlantic states	2,226,488	120	5.38	117‡	5.71‡
East North Central states	8,117,000	137	1.69	174	2.19
East South Central states	836,000	121	14.47	111	14.30
West North Central states	2,479,000	55	2.22	81	3.31
West South Central states	1,478,000	173	11.69	180	13.27
Mountain and Pacific states	3,430,795	68	1.98	73	2.19

* The table corresponding to this one, in the article Typhoid in the Large Cities of the United States in 1925, was for fifty-nine cities only. The rate it gave for the South Atlantic states (8.12) was an error—the correct rate is 6.35.

† These rates are based on the population estimates for 1925 used inTyphoid in the Large Cities of the United States in 1925.

‡ Does not include data for Jacksonville.

EDITORIAL COMMENT (JOUR. A. M. A.)

The fifteenth annual survey of typhoid mortality, published in this issue, bears testimony to the remarkable improvement in typhoid rates which has occurred in the large cities in this country since these summaries were first undertaken. Data are available throughout the whole period for fifty-nine cities, which in 1910 had a population of 21,125,340 and in 1926 an estimated population of 29,784,917. Despite this population increase of over eight million, the actual number of typhoid deaths fell from 4,143 in 1910 to 822 in 1926, and the rates per hundred thousand of population from 19.61 to 2.76. If the rate that prevailed in 1910 had been maintained in 1926, the number of typhoid deaths would have been 5,840, or more than 5,000 deaths in excess of the number actually recorded. Since a material reduction in typhoid case fatality rates has not occurred during this period, these figures mean that probably 50,000 cases of typhoid, which would have occurred in our cities in 1926 if the 1910 rate had continued, were prevented. This record is an eloquent tribute to the increasing efficiency of American sanitation.

The decline in typhoid in the large cities is probably representative of a similar decline in the general population. The mortality experience of the Metropolitan Life Insurance Company, covering more than 17,000,000 policyholders, shows that 1926 was marked by the lowest typhoid rate on record in this group (4.2), although this rate is naturally not so low as that for the exclusively urban group (2.76).

It is somewhat surprising that after a period of four years during which marked typhoid reduction did not take place, a distinct increase even occurring in 1925, a rather substantial decline should be reported in 1926, marking indeed a drop of more than 10 per cent below the previous low rate. The fact that this decline was manifest in seven of the eight geographic divisions of the United States may have important epidemiologic implications and is at least worth noting as confirmation of the widespread belief in special "typhoid years."

Great as the improvement has been, let us hope that it is only an earnest of what is to come. Our city typhoid rates still average considerably higher than the rates in a number of European cities. The recent epidemiologic reports of the Health Section of the League of Nations, although not covering exactly the same period, show that in the large cities of England and Wales (with a total population of 19,474,270) the typhoid rate for 1926 was only about 0.7, the rate for London being about 0.6 and that for Birmingham still less (0.45). The German cities as a whole did not do so well, the typhoid rates for forty-six cities (population 16,746,000) being about 2.7. This relatively high rate was due in large part to an unusual prevalence of typhoid in a certain district in Germany in September and October, 1926. The Berlin typhoid rate in 1926 was but little higher (0.8) than that of London, and the Munich rate was lower. There is therefore every prospect that a further shrinkage in typhoid mortality can be brought about in the large cities of the United States, although the progress may not be so rapid a rate in the future as it has been in the past. Urban typhoid mortality in the British Isles has reached a point not quite half what it still is in the best geographic division of the United States.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Rebuilding Reservoir that Failed at South Pasadena. Ormond A. Stone. Eng. News-Rec., 97: 172–3, July 29, 1926. Illustrated description of reconstruction of Garfield Avenue reservoir in South Pasadena which failed in 1924. Failure believed to have been due to fact that cold joints were laid in pavement slabs with no provision other than thin coating of asphalt over top of crack to allow for contraction of pavement attendant upon cooling of concrete by the water. Also, corners of structure were rounded, apparently without consideration of fact that rounding corners puts tension in pavement on slope. Counterfort walls and Ambursen type walls were considered in planning reconstruction, latter being selected as more economical. Original floor was cut into 15-foot squares and relaid with bituminous mastic joints. Inside face of new concrete work was waterproofed by coating with patent bituminous product. Reservoir was filled before walls were backfilled and close inspection failed to reveal least evidence of seepage.—*R. E. Thompson.*

Investigate Concrete Exposed to Alkali. Eng. News-Rec., 97: 150, July 22, 1926. Results of investigation undertaken by Salisbury, Bradshaw, and Taylor, Los Angeles, to determine effect of alkali on concrete in alkali soils in Southern California are summarized briefly as follows: (1) Concrete can be made, without use of extraneous substances, which will be immune to injury due to exposure to alkali. (2) Concrete which had deteriorated due to alkali exposure was found to be of inferior quality. (3) It is safe to use high quality concrete in worst alkali if concrete is completely covered with earth totally excluding exposure to air. (4) Leaner mixtures may be specified for dry than for wet alkali soils. (5) As sewer pipes and land drainage tile have part of interior surface exposed to evaporation, concrete should be of first-class quality.—*R. E. Thompson.*

Bottom Recession in Alamo Canal. Glenton G. Sykes. Eng. News-Rec., 97: 69, July 8, 1926. Data given derived from investigation of scour in Alamo Canal. Scour did not increase in proportion to discharge and maximum scour occurred at much reduced flow. Explanation of phenomenon included.—*R. E. Thompson.*

Making Electrically Welded Pipe for East Bay Conduit. Eng. News-Rec., 97: 128–31, July 22, 1926. Illustrated description of manufacture of pipe for conduit which will convey Mokelumne River water a distance of 90 miles to East Bay Municipal Utility District in California. Pipe is 65 inches in diameter and is constructed of $\frac{1}{2}$ to $\frac{7}{16}$ inch steel plates. Welding is carried out by Lincoln automatic carbon arc method. Approximate welding speed with $\frac{1}{2}$-inch plates is 12 feet per hour. Each length is subjected to severe hydrostatic test. Of 1160 sections tested 35 failed. Pipes are finally dipped in bitumastic compound at temperature of 450–460° and spirally wrapped with soil-proof covering.—*R. E. Thompson.*

Revamping the Corpus Christi Water Works System. Eng. News-Rec., **97**: 133–4, July 22, 1926. Brief illustrated description of new pumping equipment installed at Corpus Christi plant which consists of 7 motor-driven centrifugal units with extreme flexibility for double and sometimes triple pumping rates, and an oil-engine-operated generator. Pressure filters formerly employed will be replaced by gravity filters. Average consumption is 1.5 m.g.d. to estimated population of 15,000.—*R. E. Thompson.*

Skillful Blasting of Holes Through Tunnel under 30-Foot Water Head. Eng. News-Rec., **97**: 152, July 22, 1926. Brief illustrated description of method of making final blast in tunnel for irrigation system 50 miles from Denver, Colo.—*R. E. Thompson.*

Theoretical Energy Losses in Intersecting Pipes. J. C. STEVENS. Eng. News-Rec., **97**: 140–1, July 22, 1926. Mathematical discussion in which general formula is deduced and applied to particular cases such as where water flows from branch into main through a tee and where several pumps discharge into common header.—*R. E. Thompson.*

Irrigation District Served by Series of Pumping Plants. Eng. News-Rec., **97**: 224–6, August 5, 1926. Illustrated description of pumping system of Banta-Carbona Irrigation District, supply for which is derived from San Joaquin River. In plant No. 6, equipped with two 20-inch pumps driven by 250-h.p. motors and discharging under 55-foot head, use of automatic control devices for starting and stopping in accordance with water level and power supply has eliminated about 80 per cent of attendance ordinarily required in pumping systems of this size.—*R. E. Thompson.*

New Form of Bank Protection on the Sacramento River. PAUL BAILEY. Eng. News-Rec., **97**: 190–1, July 29, 1926. Illustrated description of new form of bank protection consisting of current controls, composed of tree trunks, spaced 200 feet apart along bank, extending 30 feet out into low-water channel, and pointing slightly downstream. Controls have base width of 11–14 feet and height at outer tip of 11–14.5 feet above stream bed. Tree trunks are securely lashed together with wire and fastened to cast-iron screws sunk to depth of 12–18 feet below stream bed or ground surface. Cost, $10, per lineal foot of bank, was less than that of any equally satisfactory revetment formerly constructed.—*R. E. Thompson.*

Field Welding Experience on 65-Inch Mokelumne Pipe. Arthur P. Davis. Eng. News-Rec., **97**: 912–4, December 2, 1926. Illustrated description of welding experiences on 65-inch Mokelumne pipe of East Bay Municipal Utility District, California. It was found that use of welded joints in both shop and field for first unit of line, which is 86 miles long, would effect saving of over \$4,000,000, or 30 per cent of contract price, but as previous experience was lacking, provision was made in contract for substitution of riveting at an increase in contract price if welding was not adjudged satisfactory. Increase was to be 40 per cent of difference between welded and riveted pipe. About 26,000 feet of line was connected by butt-welded circumferential joints, but as a considerable percentage of field joints were unsatisfactory and had to be done over, riveted joints were then substituted. The longitudinal electric welds, made under shop conditions, have proved satisfactory. In field welding the oxyacetylene process was used on outside of pipe, an electric arc being used on inside to supplement or "back up" the external weld and to ensure proper fusion of internal edges. Physical and microscopical examinations indicated that electric weld on inside of joints improved the condition of the oxyacetylene weld, having effect of normalizing it and increasing its tensile strength. Oxyacetylene welding, being a rather slow process, caused much expansion of pipe metal and introduced unequal internal stresses in different parts of circumference, sufficient in numerous cases to cause joints to crack open as completed weld cooled. In an extreme instance, in attempting to complete 2-foot length of weld which had unusual width of 1 inch at far end, it was found that before weld had been completed this 1-inch gap had closed up tightly and part of plate had to be cut out before weld could be finished. Another difficulty was due to temperature differences caused by sun, which at times amounted to 80°F. between top and bottom of pipe. Pipe which had been delivered when change was made to riveted joints were lap-welded by means of butt strip placed entirely around joints and welded at both edges inside and out with electric arc. About 1.3 miles were connected in this way with very good results.—*R. E. Thompson.*

Securing High Early Strengths from Ordinary Portland Cement. H. S. van Scoyoc. Cont. Rec., **40**: 52, 75–6, 1926. High early strength may be obtained by (1) use of $CaCl_2$ in proportion of about 2 per cent by weight of the cement; (2) use of low water-cement ratio; (3) placing concrete at temperature as near 70°F. as possible; (4) mixing concrete for at least 2½ minutes after all materials have been added; and (5) curing concrete in a moist atmosphere as near 70°F. as possible. A compressive strength of 2,000 pounds per square inch may be obtained in 24 hours by the use of $CaCl_2$. Calcium chloride free from MgO and $CaOCl_2$ must be employed, and, as the results vary with the chemical and physical characteristics of the cement, tests should be first carried out with the particular brand of cement used.—*R. E. Thompson* (*Courtesy Chem. Abst.*)

Building Small Concrete-Lined Earth Reservoir. J. P. Bailey. Eng. News-Rec., **97**: 1082–3, December 30, 1926. Illustrated description of construction of 14-m.g. service reservoir in Oneida, N. Y. Reservoir is 230 by

230 feet, with semi-circular ends having radii of 115 feet. Embankment is 20 feet wide at top, with both slopes 1 on 2. Total depth is 19 feet and maximum water depth 16 feet, maintained by notch-shaped overflow channel. Slopes were paved with 6-inch slabs of concrete and bottom with 4-inch slabs, both of 1:2:4 mix. Elastite was used in all joints and all side slabs were finished with 1-inch mortar coat. Total cost was $65,711.—*R. E. Thompson.*

Removal of Oil from Boiler Feed Water. J. C. Dijxhoorn. Dutch 14,335, February 15, 1926. From Chem. Absts., **20**: 1482, May 10, 1926. Filtration of oil-containing feed water through filter press provided with thin layer of aluminum hydroxide (either directly applied or added to water) removes finely emulsified oil completely.—*R. E. Thompson.*

Concrete Arch Bridges Support Clarifier Mechanism. Lorenz G. Straub. Eng. News-Rec., **97**: 619–20, 1926. Illustrated description of clarifier installation in the new water softening and Fe removal plant in Springfield, Ill., in which, for esthetic reasons, concrete arch structures were adopted in place of the steel bridges usually employed.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Progress in the Purification of Water Supplies. Norman J. Howard. Cont. Rec., **40**: 52, 151–5, 143–4, 1926. A review of progress in the treatment of water, including filtration, coagulation, softening, correction of corrosiveness, iodization, and chlorination.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Interest During Construction not a Capital Charge for Taxes. Eng. News-Rec., **97**: 1085, December 30, 1926. The United States Board of Tax Appeals, in case of Spring Valley Water Co. against Commissioner of Internal Rvenue, has ruled that "Interest paid by a water corporation on borrowed funds used in the construction of a dam may not be included in the cost of the dam in determining the amount deductible as a loss upon its destruction." From 1913–1918 the company was engated in building dam on Calaveras Creek with funds borrowed by it for general corporate purposes. Interest computed monthly, which amounted to $38,224.51 for years 1913, 1914 and 1915, was deducted from gross income returns and was allowed by the commissioner. On March 24, 1918, a slide occurred at the dam whereby a considerable part was destroyed and lost to company without compensation. In its income tax return for 1918 the company deducted from its gross income the sum of $460,000, representing alleged loss sustained through destruction of dam. The commissioner, in auditing return, increased net income by the sum of $38,224.51, disallowing its inclusion in loss.—*R. E. Thompson.*

Factors Other Than Dissolved Oxygen Influencing the Corrosion of Iron Pipes. J. R. Baylis. Ind. Eng. Chem., **18**: 370–80, 1926. From Chem. Absts., **20**: 1381, May 10, 1926. Maximum iron concentrations reached in natural waters containing carbon dioxide and calcium salts are much less than theoretical solubility of ferrous hydroxide. Data on solubility of ferrous carbonate in presence of calcium carbonate given. Continuation of corrosion under rust layers depends on diffusion of soluble iron chlorides and sulfates. Pitting occurs under breaks in impervious rust membrane. Some iron oxides are magnetic and cling to metal surface.—*R. E. Thompson.*

St. Catharines, Ont., Has Model Water Filtration Plant. ALEX. MILNE. Cont. Rec., 40: 52, 209–11, 1926; 41: 7–13, 1927. The history of the water supply of St. Catharines, derived from Lake Erie via the Welland Canal, is outlined and the new filtration plant is described in detail and illustrated. The plant consists of coagulation basins providing a retention period of 1¾ hrs., 12 rapid sand filters, and a clear water basin.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Filtration Plant with New Features. Cont. Rec., 40: 879–83, September 15, 1926. Illustrated description of new filtration plant of Metropolitan Water Board of London, England, at Walton, consisting of system of double filtration—rapid sand primary filters and slow sand secondary filters. Apparatus has been provided for treating water with chlorine should this be found necessary. There are 18 rapid sand filters of 1–2 m.g.d. capacity when operated at 100–200 gallons per square foot per hour, and 6 slow sand filters each of an area ⅝ acre. It is expected that latter will be operated at 300–400 per cent of normal rate for slow sand filters. The rapid sand filters are of two types—supplied by Candy Filter Co., and the Paterson Engineering Co. The former are equipped with an arrangement which automatically closes filtered water outlet when water reaches correct level for washing after raw water has been shut off, and which gradually opens filtered water outlet when washing has been completed. This apparatus and the Module or rate controller, and the Paterson patented filter under-drain system are described in detail and illustrated.—*R. E. Thompson.*

Composition of Imported Bottled Waters. A. E. MIX and J. W. SALE. J. Am. Med. Assoc., 85: 1963–7, 1925. From Chem. Absts., 20: 1481, May 10, 1926. Imported and domestic waters are classified under their predominating mineral constituents as follows: dolomitic limestone, Vichy type, sodium bicarbonate, sodium chloride, magnesium sulfate or sodium sulfate, or both, and iron type. Over 250 imported waters were analyzed and classified.—*R. E. Thompson.*

Two Arch Dams Fail Through Undermining of Abutments. Eng. News-Rec., 97: 616–8, October 14, 1926. Illustrated details given of failure of two similar thin concrete arch dams within past 18 months through destruction of one abutment. One dam was that of Cyanide Gold Mining Co., on Moyie River in Idaho, the other that of Lake Lanier Development Co., Tryon, N. C. In both cases, a very unusual flood overtopped dam and washed out soft rock against which it abutted by first undermining and washing out spillway channel which was put in to protect rock. In second case, failure occurred through simple undermining of cyclopean masonry abutment which had been built at end of dam to replace unsound rock. In both cases the thin concrete arch dam itself withstood the pressure.—*R. E. Thompson.*

Brush, Wire Mesh and Old Rails Make River Retards. Eng. News-Rec., 97: 576–7, October 7, 1926. Brief illustrated description of retards on Fountain River, Pueblo, Col., consisting of old 60-pound rails driven into shale and covered with heavy woven fence wire backed up by brush.—*R. E. Thompson.*

Protections Against River Bank Erosion. A. W. Rogers. Eng. News-Rec. 97: 1089–90, December 30, 1926. Brief illustrated description of application of protection works similar to that described in previous abstract in the West Indies.—*R. E. Thompson.*

Water Inlet, Screen and Aerator for Liverpool Water Filters. Eng. News-Rec., 97: 539, September 30, 1926. Brief illustrated description of inlets to 3 new slow sand filters at Liverpool, England, which are designed to deliver influent in thin sheet over long weir or as fine spray from orifices in pipe placed above weir. Primary object of aëration is to relieve filters by pre-oxidation of organic matter and to convert ferrous to ferric salts. Untreated water has color of 6.5 "as measured by tintometer," which is reduced to 3.5 by old filters and to 3–3.5 by pre-aëration and new filters. The latter, like the 12 old ones, are 0.8-acre in area and are operated at rate of 2.4 U. S. m.g.d. With one bed out of commission this provides combined capacity of 33.6 U. S. m.g.d., which is about 65 per cent of daily supply.—*R. E. Thompson.*

Portable Apparatus for Determining Residual Chlorine and Turbidity. H. H. Gerstein. Eng. News-Rec., 97: 636, 1926. Brief illustrated description of portable apparatus for comparing unknown turbidity or residual Cl (o-tolidin method) with standards.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

New Tests for Concrete Workability. Eng. News-Rec., 97: 955, December 9, 1926. Brief description of tests made at Bureau of Standards in coöperation with Celite Products Co. Test experimented with was modification of penetration test developed by the Bureau several years ago.—*R. E. Thompson.*

Inlet Screen and Aërator for Water Filters at Liverpool, England. J. R. Davidson. Eng. News-Rec., 97: 1090, December 30, 1926. Additional information regarding aërators provided in new filters at Liverpool. The spray jets are intended for use in ordinary working, when weather conditions permit. During high winds the water will be delivered in thin sheet, as loss from spray being blown away is considerable. Comparisons of respective efficiencies of the two methods will be made.—*R. E. Thompson.*

22,000 h. p. Hydro-Electric Plant on the Batiscan River. Cont. Rec., 40, 1110–2, November 24, 1926. Brief illustrated description of plant of North Shore Power Co., recently put into service. Dam on Batiscan is approximately 1400 feet long and consists of two earth embankments, one each side of river, three sluiceways each 25 feet wide, and 120 feet of spillway.—*R. E. Thompson.*

How to Measure and Estimate Concrete. Cont. Rec., 40: 904–6, September 22, 1926. Methods adopted as standard by American Concrete Institute are given.—*R. E. Thompson.*

Urges that New York City Go to Housatonic River for Water. Eng. News-Rec., 97: 921–2, December 2, 1926. Brief suggestion by Geo. R. Wadleigh that Housatonic River should be considered as source of additional supply for New York City, and reply to same by the editor of Eng. News-Rec.—*R. E. Thompson.*

Vertical Butterfly Gates on Exchequer Dam. Eng. News-Rec., 97: 344–5, August 26, 1926. Illustrated description of 168-foot spillways, equipped with 7 vertical-shaft steel gates of butterfly type, at each end of recently completed Exchequer Dam on Merced River in California. The gates, which are 24 feet in length, 14 feet in height and 3 feet in thickness, are operated by two 20-h.p. motors mounted in car which moves along standard-gage track on top of dam.—*R. E. Thompson.*

Crest Gates on Dams. H. K. Higgins. Eng. News-Rec., 97: 352, August 26, 1926. Discussion of formula and diagram for weight of crest and head gates for dams and canals given in Eng. News-Rec., 96: 499, March 25, 1926, and revised in Eng. News-Rec., 96: 661, April 22, 1926.—*R. E. Thompson.*

Cost of Pipe Line Excavations. A. T. Cushing. Eng. News-Rec., 97: 434–5, September 9, 1926. Diagrams given for estimating cost of excavations for pipe lines.—*R. E. Thompson.*

Kansas City Water Tunnel Blast Caused by Natural Gas. Eng. News-Rec., 97: 552–3, September 30, 1926. Findings given of committee of engineers named by city manager of Kansas City to investigate recent explosion in water tunnel under construction. Explosive substance described as "shale gas" and igniting spark is believed to have been from closing of switch to start motor-driven pump or from motor itself.—*R. E. Thompson.*

Water Hammer Not So Important Under Highest Heads. Eng.News-Rec., 97: 577, October 7, 1926. Graph given showing relationship between maximum water hammer and static head, computed from Joukovsky's formula. Pressure rise in penstock with instantaneous stopping of flow in pipe under 2500 feet is less than 100 per cent, whereas with 200-foot head maximum water hammer may be 400–500 per cent of static head and 900 per cent with 100-foot head. Computations made in connection with Buck's Creek plant of Feather River Power Co., in California.—*R. E. Thompson.*

Guniting Upstream Face of Dam as Precaution Against Ice Damage. Eugene Carroll. Eng. News-Rec., 97: 432, September 9, 1926. Basin Creek Dam, impounding water supply of Butte, Mont., was originally of monolithic construction with cut stone water face. In 1913 dam was heightened by 13 feet of reinforced concrete, water face being plastered by hand. During winter, with water level 18–25 feet below crest of dam, ice forming on surface was destructive to plaster face. Joints were repointed with gunite and concrete face given 3 treatments ($1\frac{1}{2}$ inches) of gunite. Previous experiments indicate that gunite will be less liable to injury from ice.—*R. E. Thompson.*

Missouri River Regulation at Lexington Bridge. L. J. SVERDRUP. Eng. News-Rec., 97: 494–5, September 23, 1926. Illustrated description of regulation works on Missouri River consisting of current retards constructed of trees with trunks lashed together in groups and anchored to 15-foot Bignell concrete piles which have average penetration of 60 feet. Majority of retards are 150 feet in length; others are 200–230 feet. Approximately 4750 lineal feet of retards were built at contract price of $58.50 per foot.—*R. E. Thompson.*

On Computing Shrinkage in Earth-Fill Dams. Eng. News-Rec., 97: 516, September 23, 1926. Discussions of shrinkage in earth-fill dams and its estimation by J. ALBERT HOLMES and FLOYD FERRIS.—*R. E. Thompson.*

Device Guides Torch in Cutting Pipe on True Bevel. Eng. News-Rec., 97: 512, September 23, 1926. Brief illustrated description of adjustable device for holding oxyacetylene torch in position such that when rotated it makes true bevel cut at any desired angle with pipe center line. Apparatus was devised by Hugh F. Brown for use during construction of 26–30-inch steel supply line of Marin Municipal Water District, California. Patent applied for.—*R. E. Thompson.*

Assembled 12-In. Pipe Lowered as Unit in Navigable Waterway. Eng. News-Rec., 97: 514–5, September 23, 1926. Illustrated description of construction of 12-inch distribution main by Spring Valley Water Co., San Francisco, across Islais Creek, a ship channel about 200 feet wide. Depth of water is now only 20 feet, but as 30-foot depth is proposed, a trench 16 feet deep was dredged to provide adequate clearance. Pipe selected was Class B flanged cast-iron with lead packed flexible joints. Bolts were of Tobin bronze and gaskets of sheet lead. Flexible joints, which are of ball-and-socket type with movement of 10° from center line, are special in that lead was poured into sockets and thoroughly hammered to force it slightly into space to be occupied by ball end. Lead filling in sockets and hold-on rings was then machined to exact spherical shape of ball to be fitted. Joints are reported to be absolutely tight under 65 pounds pressure. Pipe was lowered as unit with full pressure of 65 pounds per square inch on line.—*R. E. Thompson.*

Some Fallacies in the Valuation of Water Power. ALTON D. ADAMS. Eng. News-Rec., 97: 470–1, September 16, 1926. Discussion of contentions frequently made in court regarding market value, increased expense, lost water, constant loss, etc., to increase award of damage for water diverted to municipal supply.—*R. E. Thompson.*

Good Chimney-Building Practice. Eng. News-Rec., 97: 471, September 16, 1926. Brief discussion of good practice in chimney construction from article by D. Knickerbacker Boyd in Quarterly of National Fire Protection Association (April, 1926). Employment of standard linings of fire clay reduces exposed mortar joints from 10 to 1.—*R. E. Thompson.*

Hydraulic Data on Rapidly Rising Flood in Small Stream. D. J. F. Calkins. Eng. News-Rec., 97: 416–7, September 9, 1926. Hydraulic data given on flood on Squillchuck Creek in Washington State.—*R. E. Thompson.*

New Rubber and Fabric Staunching Device for Gates. Julian Hinds. Eng. News-Rec., 97: 254–5, August 12, 1926. Illustrated description of staunching device recently developed for radial and Stoney gates by U. S. Bureau of Reclamation. New seal, which promises largely to replace metal staunching rods, split hose, etc., is of rubber and cord fabric construction similar to that used for automobile tires. Application to 20 by 10-foot radial gates of spillway of McKay dam near Pendleton, Ore., and to 20 by 26-foot Stoney gate at inlet to Gurnsey dam in Wyoming illustrated. Specifications included.—*R. E. Thompson.*

Water Service Connection and Meter Rules at Venice, Neb. Eng. News-Rec., 97: 266–7, August 12, 1926. Water supply for summer resort known as Venice is owned and operated by Martin and Heyn Co. First cost of service and meter is borne by consumer. All material and labor required to point 18 inches beyond meter is supplied at uniform rate of $42.50. Section of regulations governing material for service pipe from meter and to and into building is given. Flat charge of $6 per year is levied in advance, with additional charge of 20 cents per 1000 gallons less 5 per cent if bill is paid within 10 days.—*R. E. Thompson.*

"Tar Scraper" on Marin Conduit Job Uses Waste Acetylene Gas. Eng. News-Rec., 97: 435, September 9, 1926. Brief illustrated description of tar scraper developed by Hugh F. Brown to remove protective coating in preparation for making welded joint in 26-inch steel pipe line of Marin Municipal Water District, Calif. Scraper utilizes acetylene from drums in which pressure has been drawn down below that considered satisfactory for welding.—*R. E. Thompson.*

Theoretical Energy Losses in Intersecting Pipe Lines. Eng. News-Rec., 97: 437, September 9, 1926. Discussion of article by J. C. Stevens (Eng. News-Rec., 97: 140) by Harold A. Thomas and reply to same by J. C. Stevens. —*R. E. Thompson.*

Endurance Testing of Metals—New Developments. Eng. News-Rec., 97: 332–3, August 26, 1926. Summary of principal results reported to Am. Soc. for Testing Materials of endurance tests of metals, including steels, copper, etc. Fatigue effects of grooves and threads, and effect of water corrosion discussed. Lowering of endurance limit by corrosion ranged for different steels from 3 to 30 per cent for slight corrosion and from 20 to 60 per cent for severe corrosion.—*R. E. Thompson.*

Flush Tunnel for Waste Concrete. Wilfred Schnarr. Eng. News-Rec., 97: 271, August 12, 1926. Flush tunnel, devised by Alex. Robertson during construction of extension to Nipigon Powerhouse of Hydro-Electric Power Commission, Ontario, for keeping bottom of pit at foot of concrete shooting tower free from concrete drippings, is described briefly and illustrated.—*R. E. Thompson.*

Factors Governing Air Inlet Valves on Pipe Lines. D. C. Henny. Eng. News-Rec., 97: 294–7, August 19, 1926. Mathematical discussion. Theoretically, if pipe is truly round and if backfill is well tamped without causing deformation, any ordinary pipe, even if built of thin steel plate, should have abundant strength to resist atmospheric pressure when complete vacuum exists on inside. Pressure then is radially inward and, in case of 24-inch No. 10 gage steel pipe, would stress steel only to 1300 pounds per square inch. It is well known that collapse, when it occurs, is not due to lack of compressive strength in steel of round pipe but to its lack of strength as an arch when deformed and carrying unevenly distributed loads.—*R. E. Thompson.*

Cross-Connections Eliminated at Buffalo. Eng. News-Rec., 97: 259, August 12, 1926. Reported that all cross-connections between city water supply and questionable sources have been eliminated by July 1, in accordance with resolution adopted by New York State Public Health Council. In all cases plants having cross-connections expressed willingness to coöperate when notified.—*R. E. Thompson.*

How Typhoid Was Cut Down at East Liverpool. Eng. News-Rec., 97: 297, August 19, 1926. Water supply is obtained from Ohio River. During 4 years preceding completion of water treatment plant in 1918, average typhoid death rate was over 75 per 100,000. During succeeding 4 years plant was operated under direction of part-time consulting analyst and average typhoid rate was 38 per 100,000. During 3 years ending 1925, with plant operated under direction of full-time chemist-in-charge, only 2 deaths have occurred, one each in 1923 and 1924 and none in 1925. Rate in 1921 was 55.3; 1922, 18.2; 1923, 4.5; 1924, 4.4; and 1925, 0. Estimated population in 1925 was 22,900.—*R. E. Thompson.*

Dam Construction in Winter on the Androscoggin. Eng. News-Rec., 97: 326–331, August 26, 1926. Illustrated description of construction of dam of Gulf Island hydro-electric plant of Central Maine Power Co. Dam is 2600 feet long, 1323 feet being of concrete, maximum section of which is 110 feet high. Dam will form pond about 10 miles long and one mile wide (maximum) holding about 4,000,000,000 cubic feet. No uncommon winter placing methods were employed but common methods were applied thoroughly, which added 12–15 per cent to normal warm weather cost. Concrete left mixer at 80–90° and placed concrete was sheltered with canvas and kept warm by means of steam jets. In first winter's works there was not a fault in concrete due to freezing. Total cost of development will be about $5,000,000.—*R. E. Thompson.*

Laying 42-In. Concrete-Pipe Sewer on Ocean Bottom. Eng. News-Rec., **97**: 292–3, August 19, 1926. Illustrated description of construction of concrete outfall sewer extending 3214 feet into Pacific Ocean, terminating in water depth of 45 feet. Joints first laid were made wholly with asphaltic compound. Later improvement was use of rope of loose strands of oakum coated with liquid bitumastic in conjunction with asphaltic compound which would swell in event of failure of latter. Joints disturbed by earthquake during construction were calked with lead wool, use of 99 per cent wool being found advisable. On last day of construction, 5 sections were laid with diver below only 1¾ hours.—*R. E. Thompson.*

Behaviour of Flexible Reinforced-Concrete Mattresses as Bank Protection on Deep Rivers. B. Okazaki. Eng. News-Rec., **97**: 248–250, August 12, 1926. Data given on flexible reinforced-concrete mattresses as bank protection in lower portion of Ishikari River (one of two largest rivers in Japan, draining 6,000 square miles) where channel depth in front of natural caving bank varies from 25 to 50 feet at low water stage and from 37 to 60 feet in flood time. Total length of protected bank is 35,982 feet. Initial cost is $6.35 per lineal foot and maintenance cost 15 cents per lineal foot per year. On basis of assumed probable life of 20 years, sum of annual allotment of first cost and maintenance is 46.8 cents per foot. Costs of protection works at mouth of Liao River, involving several mixed systems ofrevetment, given for comparison: initial cost $20.47, annual repair cost $1.135 and sum of annual allotment and maintenance $3.182 per lineal foot. Method of construction described and illustrated. Galvanized wire has been in use as long as 15 years in Japan without suffering appreciably from rusting.—*R. E. Thompson.*

Draft Tube Lined With Cast-Iron at Big Creek No. 8 Plant. Eng. News-Rec., **97**: 182–3, July 29, 1926. Brief illustrated description of reconstruction of draft tube of plant of Southern California Edison Co., on San Joaquin River. Lining was constructed of cast-iron, 1¼ inches thick, made in 8 sections.—*R. E. Thompson.*

Leakage Tests on Steel Water Mains. Eng. News-Rec., **97**: 209, August 5, 1926. Brief data given on results of tests for leakage of 42- to 60-inch Lockbar steel pipe recently laid in Detroit. Arbitrary limit of leakage specified was 1 gallon per day per foot of pipe regardless of diameter, equivalent to 88,110 and 126 gallons per day per inch diameter per mile of pipe for 60-, 48- and 42-inch pipe respectively.—*R. E. Thompson.*

Boiler Compound. W. P. Peck, U. S. 1,579,949, April 6. From Chem. Abst., **20**: 1679, May 20, 1926. Boiler cleaning mixture is formed from extract of hemlock 40 pounds, sodium carbonate 60 pounds, brown sugar, 10 pounds, and water 30 gallons.—*R. E. Thompson.*

Keeping Salt Water Out of Lock-Controlled Waterways. W. M. Meacham. Eng. News-Rec., **97**: 219–20, August 5, 1926. Conclusions derived from study to determine cause of salt contamination of water in Lake Washington Ship

Canal at Seattle given, together with plans for exclusion of salt water. Presence of salt renders water unfit for use as supply for domestic and boiler purposes. Chemical diffusion of salt upward through body of fresh water is so slow that it is negligible. Mechanical diffusion, including mixing due to convection currents, is material factor.—*R. E. Thompson.*

Experimental Deformation of a Cylindrical Arched Dam. B. A. Smith. Proc. Am. Soc. Civ. Eng., 52: 8, 1596–1601, October, 1926. This paper gives experimental confirmation of the author's formulas on arched dams.—*John R. Baylis.*

Venturi Tube Characteristics. J. W. Ledoux. Proc. Am. Soc. Civ. Eng., 52: 9, 1787–96, November, 1926. Author discusses the Venturi tube and gives coefficients of discharge and losses of head determined from a series of tests. Nineteen tubes ranging in size from 30-inch to 1-inch were used. Effects of angles of convergence and divergence, of tube ratios, and of size of tubes on coefficient of discharge and on loss of head, are discussed. Conclusion is reached that for Venturi tubes ranging in size from 4 to 30 inches, the coefficient of discharge is approximately the same and ranges from 0.96 to 0.985, with an average of about 0.977, for high velocities, and from 0.90 to 0.94 for low velocities. Opinion is given that Venturi tube is only surpassed in accuracy by actual weighing or volumetric measurements. A V-notch or rectangular weir is excellent for approximate measurements, but is not sufficiently accurate for checking a well-designed Venturi tube.—*John R. Baylis.*

Storage Required for the Regulation of Stream Flow. Charles E. Sudler. Proc. Am. Soc. Civ. Eng., 52: 10, 1917–55, December, 1926. This paper presents a study followed by a set of curves for determining the dependable stream flow to be expected due to a given reservoir capacity. The author finds that Hazen's "seasonal storage curves" can be depended upon, and has developed extensions to them. Consideration is also given to those factors due to which a reservoir located on a tributary, or at a point some distance up stream from the point of use, may be less useful than one having a point of use corresponding with the dam site. A series of curves for predicting the dependable flow at the point of use are given. A number of computations are made, assuming storage capacities and rates of use as determined by the diagrams, and applying them to various streams for which flow records covering a period of years were available.—*John R. Baylis.*

Water Analysis Conversion Factors. Anon. Ry. Rev., 79: 18, 662, 1926.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Excelsior Filters for Water Treating Plants. W. M. Barr. Ry. Engineering and Maintenance, 23: 1, 28–29, and 2, 45. Barr is convinced that excelsior filters are the most satisfactory filtration medium for railroad water treating plants, although this fact is disputed by others.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Sand versus Excelsior Filters. C. R. KNOWLES. Ry. Engineering and Maintenance, 23: 3, 90, 1927. Experience on Ill. Cent. R. R. indicates sand superior to excelsior as a filtration medium.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Sludge Remover for Locomotive Boilers. Anon. Ry. Age, 81: 25, 1230, 1926. New device consists of operating rod connected to double blow off cocks with slotted copper pipes in water legs.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Norfolk and Western Builds Large Water Treating Plant. Anon. Ry. Rev., 79: 16, 609–610, 1926. The Norfolk and Western Ry. has completed final units of a 5,400,000-gallon per day softening plant at their Roanoke, Va., terminal. Water is pumped from the Roanoke River to a 2,000,000-gallon concrete sedimentation basin where alum coagulation and chlorine treatments are given. The softening plant consists of two units, each of 125,000 gallons per hour capacity with steel tanks 50 feet and 55 feet diameter by 35 feet high with excelsior filters at the top. Chemical proportioning device is of the tipping bucket type. Normal hardness of raw water is 10 grains per gallon in addition to which 1,000 tons of mud are removed annually. Clear water storage facilities consist of one 200,000-gallon concrete and one 400,000-gallon steel elevated tank. Saving from purification is estimated at $250,000 per year.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Southern Pacific Softens Water by Zeolite Method. C. W. STURDEVANT. Ry. Age., 81: 15, 675–676; Ry. Rev., 79: 15, 537–538, 1926. The Southern Pacific R. R. has nine zeolite plants in operation and five more under construction. Advantage of system lies in automatic proper chemical proportioning and low cost of operation where NaCl is available at reasonable rate. Regeneration requires ½ pound NaCl per grain of hardness per gallon for every 1,000 gallons treated. Waters treated vary from 11 to 34 grains per gallon incrusting matter. Some foaming trouble has been experienced. No evidence has occurred as yet of corrosion from treated water or of caustic embrittlement. Marked reduction in cost of boiler maintenance has been made.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

A Profitable Investment. Editorial. Ry. Rev., 79: 15, 546, 1926. By volume and weight, the water consumed annually on railroads exceeds all other material. Statistics indicate that over 100,000,000 lbs. of scale forming matter is removed annually at 1,200 softening plants effecting remarkable savings.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Fuel Consumption Cut Seventeen Per Cent. Ry. Rev., 79: 14, 491–495, 1926. Installation of the Dabeg feedwater heater on the Delaware and Hudson effected a saving of 17 per cent in locomotive fuel. This type is in use and was developed on the Austrian Federal Railways. It is a combination open type pre-heater with automatic boiler feed pump. Complete test statistics and installation diagram are shown.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Pitting of Locomotive Boilers. W. A. Pownall. Ry. Rev., 79: 8, 263–270, 1926. Causes assigned as contributing to pitting are: stopped up flues; mud and scale in barrel of boiler; poor circulation; trapping of O_2 and CO_2; rusting of boiler material before used in boilers; acid water; salt water; organic matter; and any chemical condition whatever of feed water that increases the electrical potential difference between boiler metal and water. Remedies offered are: use of corrosion resistant materials; maintenance of proper caustic alkalinity in boiler water: avoidance of high salt, iron, and acid waters; improved circulation; thorough boiler washing; rejection of rusted material; and avoidance of cinder accumulation against flue sheet or in flues.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Corrosion an Electro-Chemical Phenomenon. L. O. Gunderson. Ry. Rev., 79: 10, 335–343, 1926. Review of theory with emphasis on electrochemical and special attention to thermal electrolytic effect. To inhibit corrosion, the H-ion concentration should be reduced to a minimum and O_2 removed from the water, or anti-corrosive influences established adjacent to interior boiler surfaces by electrical means. Experiments indicate that thin coating of arsenic on boiler metal will afford protection. Experiments are being conducted in yard engine and passenger locomotive with the electrolytic system. Installation diagram for electrolytic polarization system is shown. —*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Embrittlement of Boiler Plate. Anon. Ry. Rev., 79: 17, 619–624, 1926. Detailed abstract of report by S. W. Parr and F. G. Staub at A. S. T. M. 1926 convention.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

How Wrought Iron is Manufactured. Charles T. Ressler. Ry. Rev., 78: 24, 1075–1077, 1926.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Regulations of Federal and State Authorities Pertaining to Drinking Water Supplies and Sanitary Examinations of Drinking Water Supplies. Com. Rep. Amer. Ry. Engr. Assoc., 28: Bull. 292, 225–226. Progress report.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Pitting and Corrosion of Boiler Tubes and Sheets. Taking into Consideration Character of Metal Used, Method of Manufacture, Construction of Boilers, and Quality of Water. Com. Rep. Amer. Ry. Engr. Assoc., 28: Bull. 292, 226–227. Progress report mentions test being made on O_2 removal with open type feed water heater.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

Cost of Impurities in Locomotive Water Supply and the Value of Water Treatment. Com. Rep. Amer. Ry. Engr. Assoc., 28: Bull. 292, 227–229. Progress report.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

NEW BOOKS

La Concentration en Ions Hydrogène de l'Eau de Mer. R. LEGENDRE. Paris: Les Presses Universitaires de France. 287 pp. Fr. 30. From Chem. Abst., 20: 1025, April 10, 1926.—*R. E. Thompson.*

Water Sterilization by Gaseous Chlorine. London: The Paterson Engineering Co., Ltd. From Chem. Abst., 20: 1126, April 10, 1926.—*R. E. Thompson.*

Die Mineralquellen und Kurmittel des Iodbades Tölz mit besonderer Berücksichtigung ihrer Anwendungsweise. EMIL MORGENSTERN. 5th edition, revised and enlarged. Bad Salzungen; L. Scheermesser. 91 pp. R.M. 1.50. From Chem. Abst., 20: 1292, April 20, 1926.—*R. E. Thompson.*

The Colorado River Compact. REUEL LESLIE OLSON. Cloth; 6 x 10 inches; pp. 527. $8, from author. Reviewed in Eng. News-Rec., 97: 472, September 16, 1926.—*R. E. Thompson.*

Der Genauigkeitsgrad von Flügelmessungen bei Wasserkraftanlagen. A. STAUS. Berlin: Julius Springer. Paper; 6 x 9 inches; pp. 35. 2.4 reichmarks in Germany. Reviewed in Eng. News-Rec., 97: 840, November 18, 1926.—*R. E. Thompson.*

Waterworks Administration: Being a Practical Guide to the Solution of the Many Problems to be met with in the Business Management of a Public Water Supply Undertaking, and Containing Some Suggestions for the Amendment of Waterworks Law. W. H. PARSONS. London: P. S. King & Son, Ltd. Cloth; 6 x 9 inches; pp. 309. 18s. Reviewed in Eng. News-Rec., 97: 841, November 18, 1926.—*R. E. Thompson.*

Steam Turbines. GIUSEPPE BELLUZZO. Translated by A. G. BREMNER. London: Charles Griffin & Co., Ltd., Philadelphia: J. B. Lippincott Co. Cloth; 6 x 9 inches; pp. 732. $17.50. Reviewed in Eng. News-Rec., 97: 842, November 18, 1926.—*R. E. Thompson.*

Guiding Principles of Public Service Regulation, Volume 3. HENRY C. SPURR. Public Utilities Reports, Inc. Drawing from his extended experience as editor of "Public Utilities Reports" and his familiarity with cases in which public utility matters are involved before courts and commissions, the author has rearranged and amplified the series of editorials that have been appearing currently during the past year in the advance sheets of P.U.R., and has worked them into 865 pages and 26 chapters, covering in a comprehensive way the guiding principles on Return, Cost Factors, and Rate Schedules laid down by our regulatory and judicial bodies. Almost 4000 cases are cited, involving every kind of utility service, and are so referenced as to be made readily accessible. The plan of the book follows that of the first and second volumes, previously issued, wherein questions of valuation and of service were discussed.

The return to which utilities are entitled and that below which confiscation would take place must be determined, as the author develops, in the light of what is a fair and reasonable return. There is a discussion of what return is required to attract capital, and of what weight has been given, in fixing a rate of return, to the efficiency of management, the character of service, the development of the property, the trend of prices, and other elements affecting the particular utility under review. Between the limits of confiscation and of the worth of the service, regulatory bodies have moved rather freely, with slight interference from the judiciary. It is not surprising, therefore, that the rate of return allowed has varied over a wide range, although of late it has had a tendency to settle down between 7 and 8 per cent.

The cost basis of rate making is elaborated upon and its ramifications developed. The allocation of cost is susceptible of resolution into broad principles only with difficulty, but a number of cases cited indicate the tendency in certain jurisdictions.

It is evident that of recent years guiding principles have become more pronounced, and a tendency evidenced to follow precedent, except where the individualities of any case dictate otherwise. The well established rule that property cannot be taken away without just compensation has been made to apply to the use of property and earnings therefrom. The line between regulation and management is not so clearly drawn, but commissions very generally have evidenced respect for it. No acceptable method of rewarding efficient and penalizing inefficient management has been worked out. The rate of return is the only effective instrument so far devised, although the gradual shortening of the range of variation of this factor is tending to limit its usefulness.

The practice in different jurisdictions as to the filing and publishing of rate schedules, as to their form and designation, and as to their interpretation, application, and duration is set out in the chapter on Rate Schedules. While this cannot be other than indicative only, nevertheless it may be helpful in avoiding certain pitfalls. The status of municipal contracts is of interest, especially in view of the effect of the adoption of regulatory laws.

Rates and rate schedules, flat versus meter rates, the minimum charge, the service charge, the demand charge, quantity rates, and contract rates are discussed in separate chapters. The factors to be considered in rate making, including among others the cost of service, the value of service, the economic limit, the ability of customers to pay, the effect of competition, and the usefulness of comparisons are outlined in a chapter preparatory to a series of seven chapters dealing with the rates of particular kinds of utilities.

The chapter on water rates throws much light on the way in which state commissions have been apportioning charges and the consideration they have given to the demand factor, use factor, investment, and expenses, in deciding upon rates for public and private fire protection and for domestic, commercial and industrial consumption. One section also deals with irrigation rates and another with incidental questions interesting every water works manager, such as connection charges, meter replacement charges, and charges for seasonal business.

This third volume takes its place alongside the first two and will doubtless be followed by others dealing with additional vexatious and contentious utility problems, the set forming a valuable reference work on "Guiding Principles of Public Service Regulation."—*H. Carl Wolf.*

SOCIETY AFFAIRS

INDIANA SECTION

On February 17 and 18, 1927 the Indiana Section held its annual meeting at the Claypool Hotel, Indianapolis, Ind. About two hundred men attended.

In the absence of Senator Bradford, Dr. W. F. King discussed the Izaak Walton League in its relation to stream pollution. He also reported on the Cooperative Survey of White River carried on by the Indianapolis Water Company, the Indiana State Board of Health, the Conservation Department and the Indianapolis Sanitary District.

J. K. Hoskins gave a summary of the findings of the survey of the southern end of Lake Michigan showing how pollution has increased and the effect of construction in that district on the direction of waste flows.

The Economic and Sanitary Aspects of Sewage Treatment as against Water Purification were considered by Paul Hansen. In the development of his subject he warned against dogmatic emphasis of either, suggesting that individual situations should be governed by factors peculiar to each.

John W. Moore, who has developed well water supplies in Indiana for a number of years, talked on the Economic Limit to Deep Well Production.

The water cement ratio control in concrete pouring was reported as being entirely feasible in construction by W. C. Mabee, who described concrete handling methods employed in the construction of a reservoir for the Indianapolis Water Company. The contractor found it an agreeable method of control and the resulting work was found to be of high quality.

For several years, fire protection has received close attention from the water works men. At this meeting George W. Booth and Alfred M. Hogston spoke on this subject.

Charles Brossman described novel design features of the new intake at Michigan City, showing how certain construction difficulties were overcome.

Appraisal methods are of vital interest to water supply men. H. O. Garman, formerly Engineer for the Indiana Public Service Commission, read a paper on this subject.

Joseph J. Daniels, Attorney for the Indianapolis Water Company, presented the most important features of their rate case and the United States Supreme Court decision. This case has been considered very important to public utilities.

W. H. Durbin could not be present, but his paper was read. By intensive and novel advertising, and a liberal financing plan, plumbing fixtures were placed in many houses, thereby increasing customers.

L. S. Finch, Director of the State Water and Sewage Department, presented a scheme for the classification and rating of water supplies based on physical surveys and laboratory examinations.

Though the cross connection evil has been fought for many years and some states have prohibited certain types, the subject is still of great interest and importance from a public health standpoint. A. E. Gorman gave an account of a campaign against them in Chicago.

Flood prevention was the topic of a large part of one session. C. S. Bennett, of the Miami Conservancy District, Dayton, Ohio, described some of the engineering features and data of design and outlined the method of operation.

C. C. Oberleas gave an outline of the flood prevention program planned for Indianapolis.

A resolution approving the formation of a sewage and waste treatment division of the American Water Works Association was passed by the Section. It was felt by the members that a desirable cooperation between the water and sewage men could be fostered in this way.

John W. Moore was elected president, C. E. Stewart, vice-president, and C. K. Calvert, secretary-treasurer.

C. K. Calvert,
Secretary-Treasurer.

CANADIAN SECTION

The seventh annual meeting of the Canadian Section was held in Ottawa from Wednesday, March 2, to Friday, March 4, 1927, with headquarters at the Chateau Laurier.

The convention was the most successful in the history of the

Canadian Section and the attendance was the largest on record. It was distributed as follows:

Active members	73		
Guests, actively interested in the management of water works, or chairmen or members of water boards, commissions, etc.	68		
Associate members	58	199	
Ladies		11	210

The program for the entire three days was carried out exactly as arranged, and, to show the interest of the members, there were at least forty present in the session room when the convention closed at 5.15 p.m. on Friday.

The convention opened on Wednesday at 9:30 a.m. with registration. Most of the morning was spent renewing old acquaintanceships and inspecting the interesting display of the Canadian Water Works Equipment Association in the Loge and Ball Rooms, which adjoined the meeting room. There were thirty-four exhibitors who showed and explained their supplies and their display was an instructive feature of the convention.

At noon, an informal luncheon was held in the Chateau Laurier. One hundred and sixty members and guests were present to hear Major Walter Blue, of the Gatineau Power Company, describe their extensive hydro-electric development works on the Gatineau River at Chelsea and Farmers Rapids, about twelve miles from Ottawa, which the members were to inspect the following day.

In the afternoon, papers were read by N. J. Howard, on "Some New Aspects of the Treatment of Water with Chlorine," and by A. D. Stalker, on "A Water Waste Survey." Both papers provided considerable discussion, and all members were encouraged to exchange their views on these subjects, so as to give each other the benefits of their practice and experience.

The Secretary of The Association, B. C. Little, took part in the discussion and expressed his pleasure in attending the annual meeting of the Canadian Section.

The ladies visited the House of Parliament in the afternoon and in the evening enjoyed a theatre party, given with the compliments of the Canadian Water Works Equipment Association.

In the evening, two papers were read, one by C. D. Brown, on "Office Records," and the other by Theo. J. Lafreniere, on "The Control of Water Purification Plants."

At 10:30 p.m., the members were taken in motor busses to the Highlea Club on the Quebec side of the Ottawa River, where a supper and entertainment were provided by the Canadian Water Works Equipment Association. Mr. Theo. Lanctot, the City Engineer of Hull, who was a member of the Local Committee, arranged all the details and all agreed that a more amusing and enjoyable evening's entertainment had never been provided at the annual meetings of the Canadian Section.

On Thursday, March 3, the annual business meeting was held at 9:30, and the usual proceedings, such as the appointment of Nomination and Resolution Committees, Scrutineers, reports of Membership and Hose Thread Committees, election of officers and selection of place of next annual meeting, were transacted.

The Scrutineers reported that the new officers elected for the year 1927, were as follows: Chairman, D. McL. Hanna; Vice-Chairman, J. O. Meadows; Trustee, W. E. MacDonald.

The Manufacturers reported that J. J. Salmond, was elected as their representative on the Executive Committee. The Secretary-Treasurer, elected by the Executive Committee, was A. U. Sanderson.

The remaining officers of the Executive Committee are: Trustee, W. C. Miller; Trustee, Marcel Pequegnat; Immediate Past Chairman; R. H. Starr.

London, Ontario, was selected as the place of the next annual meeting, and the question of the Standardization of Hose Threads was referred to a committee consisting of the Chairman of the Canadian Section, the Fire Marshals of the various provinces, a representative of the Dominion Fire Chiefs Association, a representative of the Canadian Standards Committee and a representative of each Section of the Fire Underwriters Association of Canada.

The Nominating Committee selected for the nomination of officers for the year 1928 were: Chester Smith, J. Clark Keith and Harry Carmichael.

The Treasurer reported that the finances of the Section were in excellent condition and stated that there was a balance of $269.00 in the bank. The auditors, N. R. Wilson and R. L. Dobbin, reported that the financial statement of the treasurer had been audited and found correct.

The Chairman regretted that the President of The Association, Allan W. Cuddeback, could not be present, but was glad to welcome B. C. Little, the Secretary, and C. R. Wood, B. B. Hodgman and John S. Ward of the Manufacturers Association.

On Thursday afternoon, the members and guests were taken by motor bus over a snow dragged highway in Quebec, a distance of twelve miles, to inspect the Hydro-Electric Development of the International Paper Company at Chelsea and Farmers Rapids. A construction train was also used to transport the members between the two large works, where 290,000 h. p. will ultimately be developed. The large dams, spillways, intakes and turbines under construction and partly in operation were viewed with interest by everyone.

In the evening, the annual dinner was held at the Chateau Laurier, and over 200 listened to an excellent address by Paul Hansen, on "Water Purification." The members were indebted to Mr. Hansen for coming such a long distance to speak at this dinner and speeches were also given by His Worship, Mayor Balharrie, Controller McElroy of Ottawa and William Gore. A splendid entertainment was also provided by certain artists with the compliments of the Canadian Water Works Equipment Association.

On Friday, March 4, a paper was read by W. E. MacDonald, on "The Ottawa Water Works," after which the members were taken by motor bus to visit a section of the Ottawa water works on Lemieux Island. The repair and meter shops and the store yards were also viewed with interest by the members. The pumping station was beautifully decorated for the occasion and the officials of the Ottawa water works were complimented on the appearance of the building and equipment and the excellent manner in which they were maintained.

On Friday afternoon, the ladies visited the Royal Mint and the Canadian National Gallery, while the members assembled for the last session. After C. R. Wood had said a few words to the members, a paper was read on "Water Rates" by J. Clark Keith, and a paper on "Fire Protection Charges" by R. L. Dobbin.

These two papers were discussed at some length, and, after the Resolution Committee had presented their resolutions, which were unanimously adopted, and a vote of thanks and appreciation to the Retiring Chairman, R. H. Starr of Orillia, had been adopted, the seventh annual meeting closed at 5.15 p.m.

A. U. Sanderson,
Secretary-Treasurer.

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